

UNCLASSIFIED

AD NUMBER

AD888969

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; 09 NOV 1971. Other requests shall be referred to Naval Air Systems Command, PMA-235B, Washington, DC 20360.

AUTHORITY

NAVAIR per ltr dtd 10 July 1975

THIS PAGE IS UNCLASSIFIED

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

AD 888969

FTC-TR-71-32

FTC-TR-71-32



A
F
F
I
C

CATEGORY II
A-7D/ARRESTING SYSTEMS
COMPATIBILITY TESTS

JAMES O. ROGERS, JR.
Second Lieutenant, USAF
Project Engineer

NATHANIEL O. ROYOLL
Major, USAF
Project Pilot/Officer

TECHNICAL REPORT No. 71-32

JULY 1971

This document may be further distributed
by any other agency with appropriate
approval. Naval Air Systems Command,
PMA-235B, Washington, D.C. 20360

DDO
RECEIVED
NOV 9 1971
C

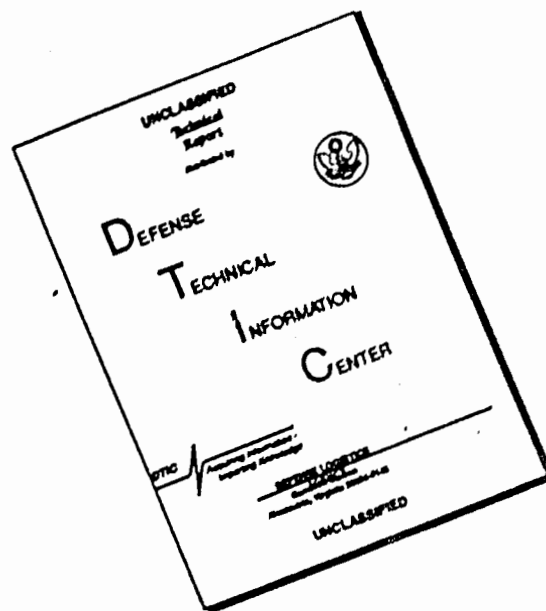
AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

Distribution limited to U.S. Gov't. agencies only;
Test and Evaluation; 9 Nov 71. Other requests
for this document must be referred to

Naval Air Systems Command
PMA-235B Wash DC 20360

84

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

PMA235B
SUPPLEMENTAL REPORT TO FTC-TR-71-32
CATEGORY II
A-7D/ARRESTING SYSTEMS
COMPATIBILITY TESTS

18 October 71

Comments relative to FTC-TR-71-32:

GENERAL

Unsatisfactory Materiel Reports (UMRs) and Deficiency Reports (DRs) submitted as a result of Category II testing will be processed and corrective action taken where feasible.

A-7D FLIGHT MANUAL CHANGES


T.O. 1A-7D-1 will be revised to incorporate the recommended changes pertaining to approach end engagements, cable disengagement, and hazards associated with blowing tires prior to arrestment.

HOOK SHOE REDESIGN

The A-7D arresting hook system was originally developed for Navy A-7 aircraft. The design was optimized for slow-speed arrestment aboard an aircraft carrier.

The hook attitude problem encountered by the AFFTC during the relatively high-speed arrestments has been solved by redesigning the shape of the hook shoe. Retrofit of all A-7Ds with the improved shoe will be accomplished.

Additional flight testing of the A-7D arresting hook system is unnecessary as the effect of altering the hook shoe geometry is predictable.


H. W. STONEBERGER
Colonel, USAF
A-7D Program Manager

FTC-TR-71-32

CATEGORY II
A-7D/ARRESTING SYSTEMS
COMPATIBILITY TESTS

JAMES O. ROGERS, JR.
Second Lieutenant, USAF
Project Engineer

NATHANIEL O. DeVOLL
Major, USAF
Project Pilot/Officer

*Details of illustrations in
this document may be better
studied on microfiche*

*This document may be further distributed
and handled only with the express
approval of Headquarters, USAF, Washington, D.C. 20331.*

FOREWORD

This report presents the results of the Category II A-7D/Arresting Systems Compatibility tests conducted at the Air Force Flight Test Center, Edwards Air Force Base, California. Seventy-four tests were completed between 23 March 1971 and 11 June 1971. These tests were conducted under the authority of AFFTC Project Directive 71-16, dated 4 September 1970 with an AFFTC priority of 31 and an Air Force Systems Command priority of 31A.


Acknowledgement is made to the arresting gear test project officer, Mr. John M. Day, for his contributions to the efficient conduct of this program, and to Mr. Robert C. Tucker, for his assistance in the preparation of this report. The contributions of First Lieutenant Thomas R. Yechout and Mr. Randall Scott who assisted in data analysis and conducting tests are also acknowledged.

Foreign announcement and dissemination by the Defense Documentation Center are not authorized because of technology restrictions of the U.S. Export Control Acts as implemented by AFP 400-10.

Prepared by:


Reviewed and approved by:

1 JULY 1971


JAMES O. ROGERS, JR.
Second Lieutenant, USAF
Project Engineer


THOMAS J. CECIL
Colonel, USAF
Commander, 6510th Test Wing


NATHANIEL O. DEVOLL
Major, USAF
Project Pilot/Officer


ROBERT M. WHITE
Brigadier General, USAF
Commander

ABSTRACT

Seventy successful arrestments of A-7D, S/N 67-14583, were made on two operational Air Force aircraft arresting systems, the standard BAK-12 and the BAK-13. Thirty-three arrestments were made with the BAK-12, and 37 with the BAK-13. As a result of six approach end engagement arrestments, changes in the Flight Manual approach end engagement procedures were recommended. Runway centerline engagements were made at aircraft weights up to 42,000 pounds. The maximum engagement speed was 167 knots at an aircraft weight of 33,000 pounds. Off-center engagements were also made up to 50 feet from the runway centerline using a 190-foot span between the runway edge sheaves of the arresting systems. Aircraft control problems were not serious except for 50-foot off-center engagements with the BAK-13. Test data indicated that the design limit hookload would only be approached at engagement speeds in excess of 190 knots for both arresting systems. Four tests resulted in missed engagements due to a combination of poor hook shoe attitude and poor cable dynamics. A change in hook shoe design was recommended. The cable dynamics problem occurred with the rail type arresting cable supports when the A-7D main gear passed between the rails. Further testing of polyurethane rails was recommended to determine optimum spacing for use with the A-7D. Except for the aircraft hook shoe design, the A-7D proved compatible with each aircraft arresting system using donut type cable supports. There were no failures of the standard BAK-12 or the BAK-13 arresting systems. Although not tested, the extended runout BAK-12 was also considered to be compatible with the A-7D aircraft based on results of this test program.

table of contents

	<u>Page No.</u>
LIST OF ILLUSTRATIONS _____	v
LIST OF ABBREVIATIONS _____	vi
INTRODUCTION _____	1
Systems Descriptions _____	1
Aircraft _____	1
Arresting Systems _____	2
Test Instrumentation and Photographic Support _____	9
Test Procedures _____	10
TEST AND EVALUATION _____	11
Operational Analysis _____	11
Approach End Engagements _____	11
Centerline Engagements _____	12
Off-Center Engagements _____	12
Hook Extension _____	13
Stores Jettison _____	13
Aircraft Braking _____	13
Rollback _____	14
Maximum Arresting Hook Engagement Speed _____	14
Aircraft Disengagement _____	14
Flight Manual Changes _____	15
A-7D Systems Evaluation _____	17
Hookloads _____	17
Hook Actuator Snubbing Loads _____	23
Hook Sideloads _____	27
Hook Bounce/Missed Engagements _____	27
Hook Shoe Wear _____	36
Aircraft and Hook Bumpers _____	36
Aircraft Tires _____	37
Arresting Systems Evaluation _____	39
BAK-12 _____	39
BAK-13 _____	39
Extended Runout BAK-12 _____	39
Cable Support Evaluation _____	40
CONCLUSIONS AND RECOMMENDATIONS _____	50
APPENDIX I - TEST DATA _____	53
APPENDIX II - DEFICIENCY REPORTS SUBMITTED FOR ACTION _____	57
REFERENCES _____	65

List of Illustrations

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
1	A-7D Arresting Hook System _____	1
2	BAK-12 Arresting Engine _____	4
3	BAK-12 Fairlead Beam _____	4
4	BAK-12 Arresting System _____	5
5	BAK-13 Arresting Engine _____	5
6	BAK-13 Fairlead Tubing and Runway Edge Sheave _____	6
7	BAK-13 Arresting System _____	6
8	BAK-12 and BAK-13 Test Installation _____	7
9	Polyurethane Rail _____	8
10	Standard Donut _____	8
11	Heavy Duty Donut _____	9
12-13	Brake Hookload Performance _____	18-19
14	Typical Quick-Look Data Traces _____	20
15-16	Aircraft Hookload Performance _____	21-22
17-18	Aircraft Actuator Assembly Performance _____	24-25
19	Hook Actuator Trace (Heavy Duty Donut Cable Supports) _____	26
20	Hook Actuator Trace (Polyurethane Rail Cable Supports) _____	26
21	A-7D Hook Attitudes _____	29-33
22	Hook Shoe Attitude at Various Degrees of Hook Travel _____	34
23	Hook Positions for a Typical Approach End Engagement _____	35
24	Lower Mounting Plate of Improved Hook Bumper after Test 74 _____	37
25	Typical Tire Damage due to Cable Rollover _____	38
26	A-7D/Arresting Systems Performance Envelope _____	41
27	Maximum Average Tape Tension Performance _____	42
28	BAK-12 Typical Hookload Time Histories _____	43
29	BAK-12 Typical Tape Tension Time Histories _____	44
30	BAK-13 Typical Hookload Time Histories _____	45
31	BAK-13 Typical Tape Tension Time Histories _____	46
32	Maximum Average Tape Tension Performance _____	47
33	Typical Cable Dynamics for Polyurethane Rails, Heavy Duty (Navy) Donuts, and Standard (Air Force) Donuts _____	48-49

list of abbreviations

<u>Item</u>	<u>Definition</u>
DR	Deficiency Report
ECP	Engineering Change Proposal
fps	frames per second
FSEP	Follow-On Systems Evaluation Program
IRIG-FM	Inter-Range Instrumentation Group-Frequency Modulation
MAC	mean aerodynamic chord (in.)
NAEC	Naval Air Engineering Center



NOT REPRODUCIBLE

INTRODUCTION

The A-7D/Arresting Systems Compatibility tests were conducted as part of the A-7D Category II Follow-On Systems Evaluation Program (FSEP) test requirements. The purpose of the test was to determine (1) if the A-7D was compatible with both the standard BAK-12 and the BAK-13 arresting systems, (2) if the A-7D hook subsystem was functionally adequate, (3) if the hook subsystem was structurally adequate, (4) reliability of the hook subsystem, (5) aircraft maintenance requirements, and (6) to validate the techniques for accomplishing both runway emergency and approach end engagements as specified in the Flight Manual, T.O. 1A-7D-1, 15 June 1970, changed 1 January 1971 (reference 1). A discussion of the compatibility of the A-7D aircraft with the extended runout BAK-12 arresting system is also included in this report.

SYSTEMS DESCRIPTION

Aircraft

The test aircraft was an A-7D Corsair II, S/N 67-14583, (A-7D production No. 2). The aircraft was equipped with a production arresting hook subsystem which consisted of a stiff shank hook, replaceable hook shoe, a hydraulic snubber to keep the hook on the runway during use, and an operational hydraulic/pneumatic actuator system to allow the pilot to raise and lower the hook from the cockpit (figure 1). The hook assembly, P/N 215-44020-1, had a design tensile strength limit of 116,000 pounds, and the hydraulic snubber actuating rod end had a design compressive strength of 21,500 pounds. The ultimate strength of the hook was 187,000 pounds.

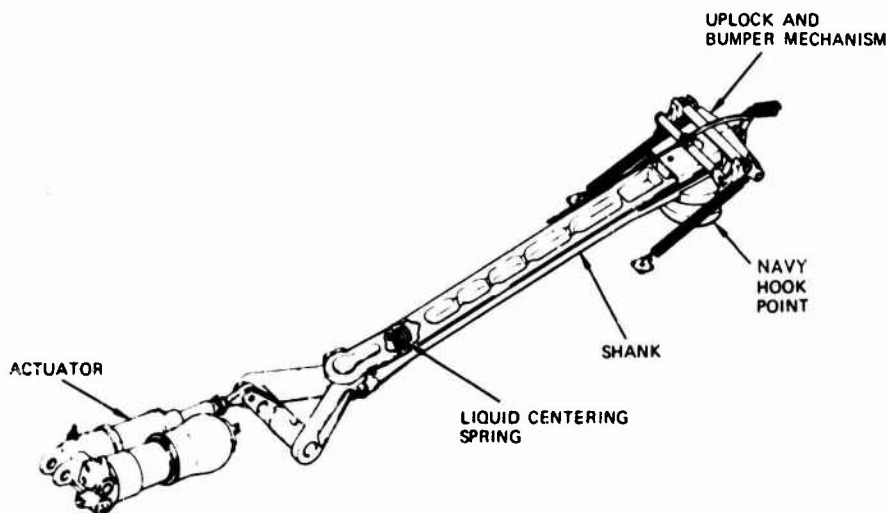


Figure 1 A-7D Arresting Hook System

Arresting Systems

The A-7D was tested against the standard BAK-12 aircraft arresting barrier and the BAK-13 Aircraft Arresting System. The standard BAK-12 is in common use in the Air Force as an emergency arresting system, and the BAK-13 is an operational arresting system in limited Air Force use at this time. General characteristics of the two systems are given in table I.

Table I

ARRESTING SYSTEMS SPECIFICATIONS

	Arresting System	
	Standard BAK-12	BAK-13
Mode of Operation	Emergency/Operational	Operational
Type of Installation	Fixed/Portable	Fixed/Portable
Type Energy Absorber	Rotary Friction	Water Turbine
Energy Capacity	65 (10 ⁶) ft-lb	85 (10 ⁶) ft-lb
Acft Design Weight	40,000 lb*	50,000 lb*
Acft Runout	950 ft	925 ft
Arresting Cable	1-1/4-inch diameter non-rotating, 18x7, improved plow steel wire rope with an independent wire rope center (IWRC)	
Arresting Cable Design Breaking Strength	125,000 lb	125,000 lb
Arresting Cable Operating Limit	75,000 lb	75,000 lb
Minimum Tape Design Breaking Strength	105,000 lb	125,000 lb
Tape Operating Limit	63,000 lb	75,000 lb

*This weight gives the most ideal aircraft hookload versus runout distance characteristic, but it is not the maximum aircraft weight which can be engaged.

BAK-12 Aircraft Arresting Barrier.

The standard BAK-12 Aircraft Arresting Barrier (T.O. 35E8-2-5-1, reference 2) was a rotary friction energy absorber with an aircraft runout of 950 feet. The BAK-12 arresting engines and fairlead beams were installed on the runway between the test site equipment pits (figures 2 to 4 and 8). The arresting system components were secured to tiedown strips which are integral parts of the runway. The span between runway

sheaves (fairlead beams) was 190 feet, and the split distance was 58 feet for the test installation. Split distance is defined as the distance between the tape leadoff sheave at the energy absorber and the runway edge sheave. The nylon purchase tapes were connected to the arresting cable with BAK-12 tape connectors.

BAK-13 Aircraft Arresting System.

The BAK-13 Aircraft Arresting System (T.O. 35E8-2-7-1, reference 3) shown in figures 5 to 7 was a hydraulic dynamometer through which braking was developed by a fluid of 40 percent water and 60 percent ethylene glycol composition resisting the motion of a bladed rotor. The nominal aircraft runout with the BAK-13 was 925 feet. The BAK-13 arresting system tested was modified by a series of Engineering Change Proposals (ECP's) to correct deficiencies including some which were believed to have resulted in tape failure during earlier tests and in field use. ECP's incorporated were:

<u>ECP No.</u>	<u>Description</u>
21439-30R	Add stationary support for upper reel side plate
21439-32R	Install wear strip with rivets.
21439-34R	Modify tight wrap roller arm hydraulic system.
21439-35R	Install new extended lube fittings and modify tight wrap roller arm to provide more clearance between lube fittings on roller arm sheave and support brackets.
21439-37R	Stiffen roller arm cylinder Z-bracket.
21439-39R	Increase inside diameter of packing gland nut.
21439-40R	Modify packing gland seal retainer and washer to facilitate removal.
21439-42R	Bolt redesign to eliminate minor shifting of deck sheave assembly on its base.
21439-45R	Install improved design lead-on/off sheave assembly to reduce possibility of tape dive.
21439-46R	Undercut inside of side plates.
21439-48R	Chrome plate diameter of tape reel hub.

The BAK-13 was installed upstream of the BAK-12 as shown in figure 8. The span between the runway sheaves was 190 feet, and the split distance was 105 feet for the test installation. The BAK-13 used the same type of arresting cable as the BAK-12 (table I).

Cable Supports.

Three types of cable supports were used to investigate wave propagation and dynamics in the arresting cable. These were polyurethane rails (NAEC P/N 613572-6) at 18-foot intervals except for the two center rails at a 14-foot interval, standard Air Force donuts (FSN 17100169067) at 5-foot intervals, and heavy duty donuts (NAEC P/N 419509-1) at 12-foot intervals (figures 9 through 11). The polyurethane rails were used on 35 test engagements with the BAK-13. Standard donuts were used on 20 test engage-

ments with the BAK-12 and five test engagements with the BAK-13. Heavy duty donuts were used on 14 test engagements with the BAK-12.

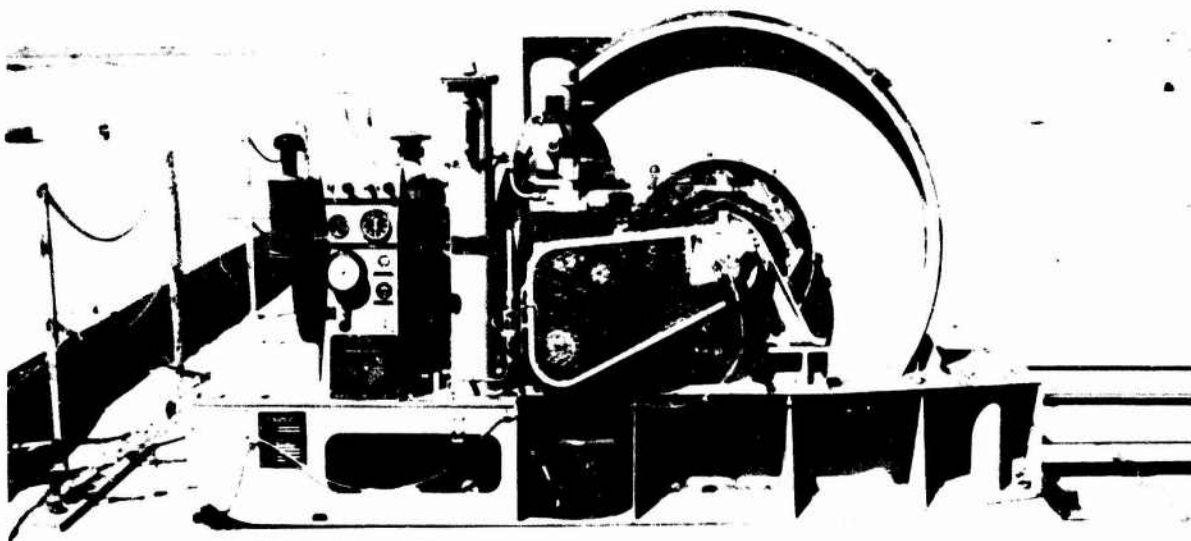


Figure 2 BAK-12 Arresting Engine

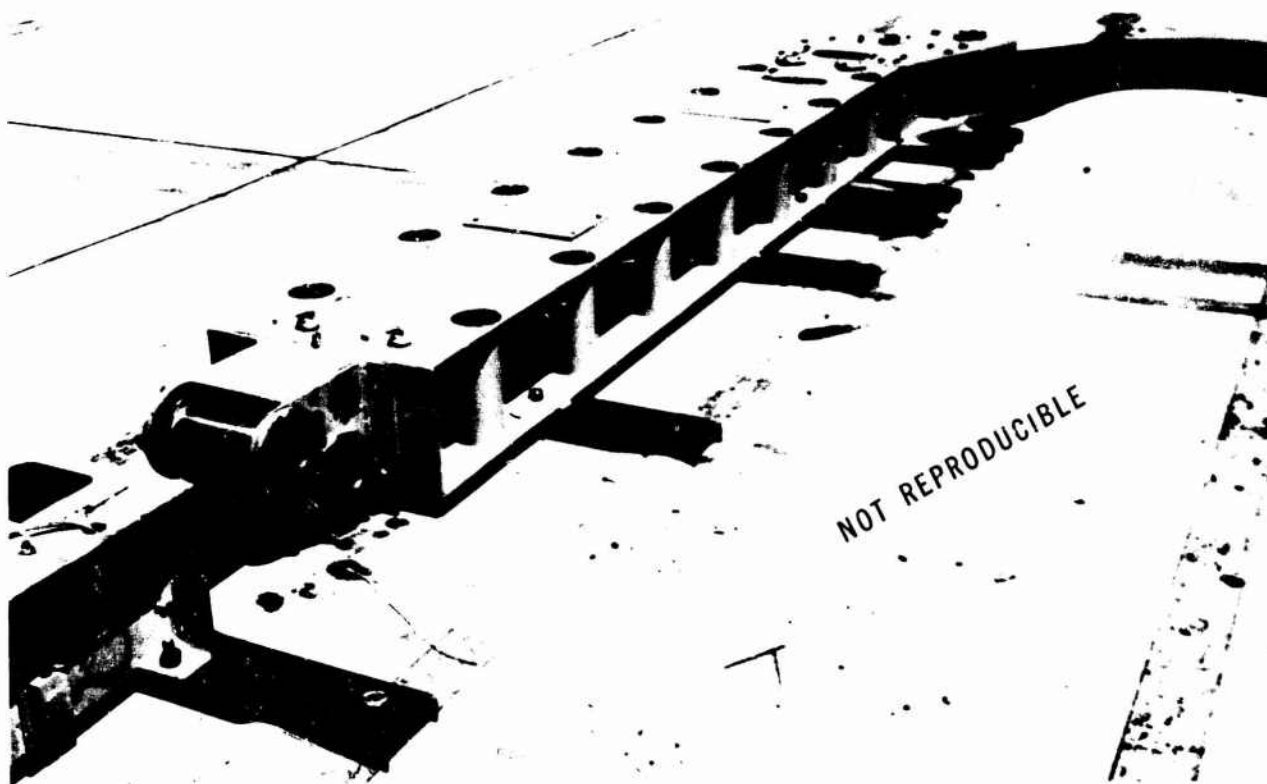


Figure 3 BAK-12 Fairlead Beam

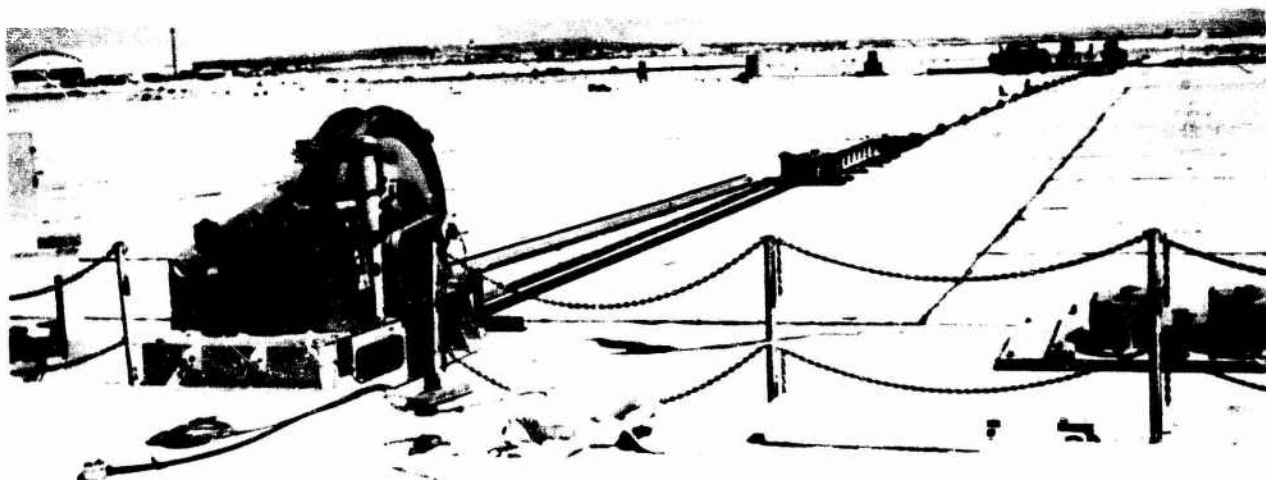


Figure 4 BAK-12 Arresting System

NOT REPRODUCIBLE

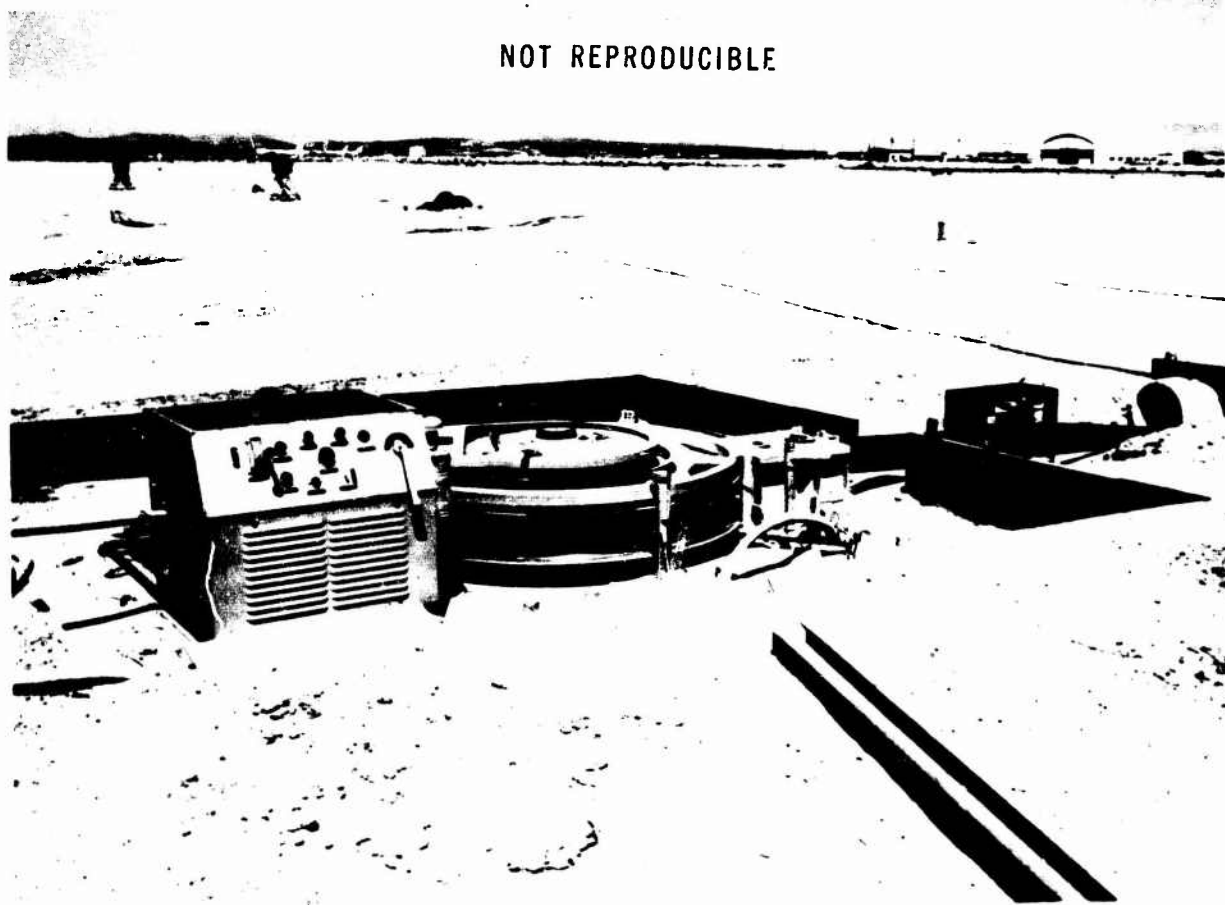
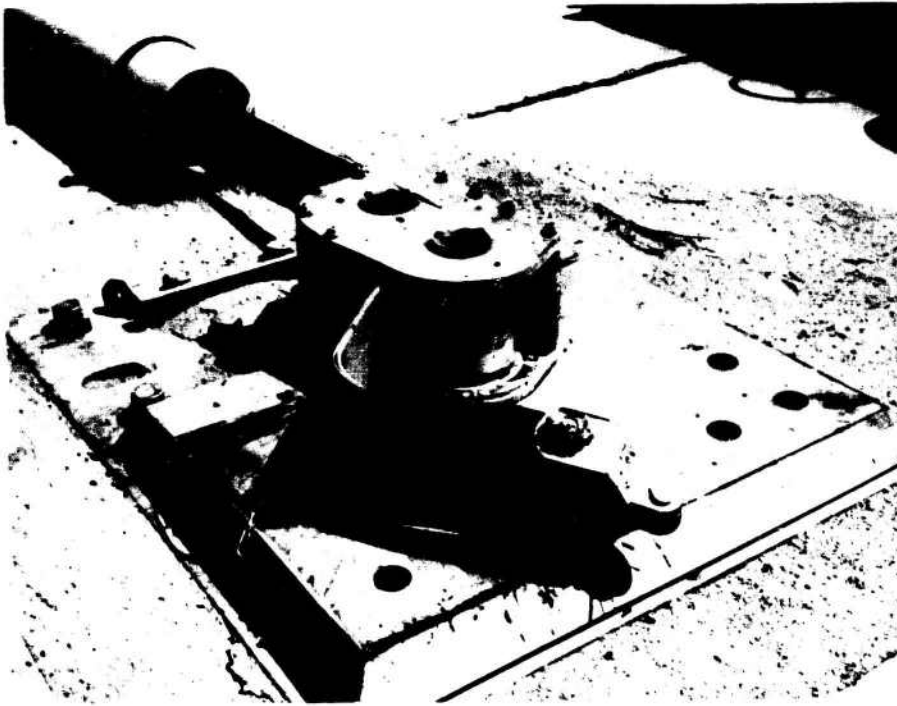


Figure 5 BAK-13 Arresting Engine



**Figure 6 BAK-13 Fairlead
Tnbng and Runway
Edge Sheave**

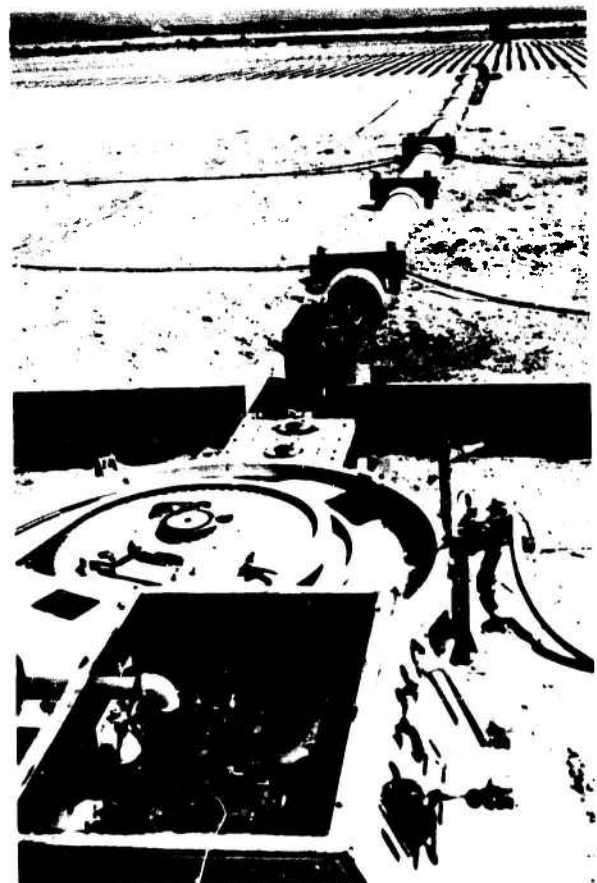


Figure 7 BAK-13 Arresting System

NOT REPRODUCIBLE

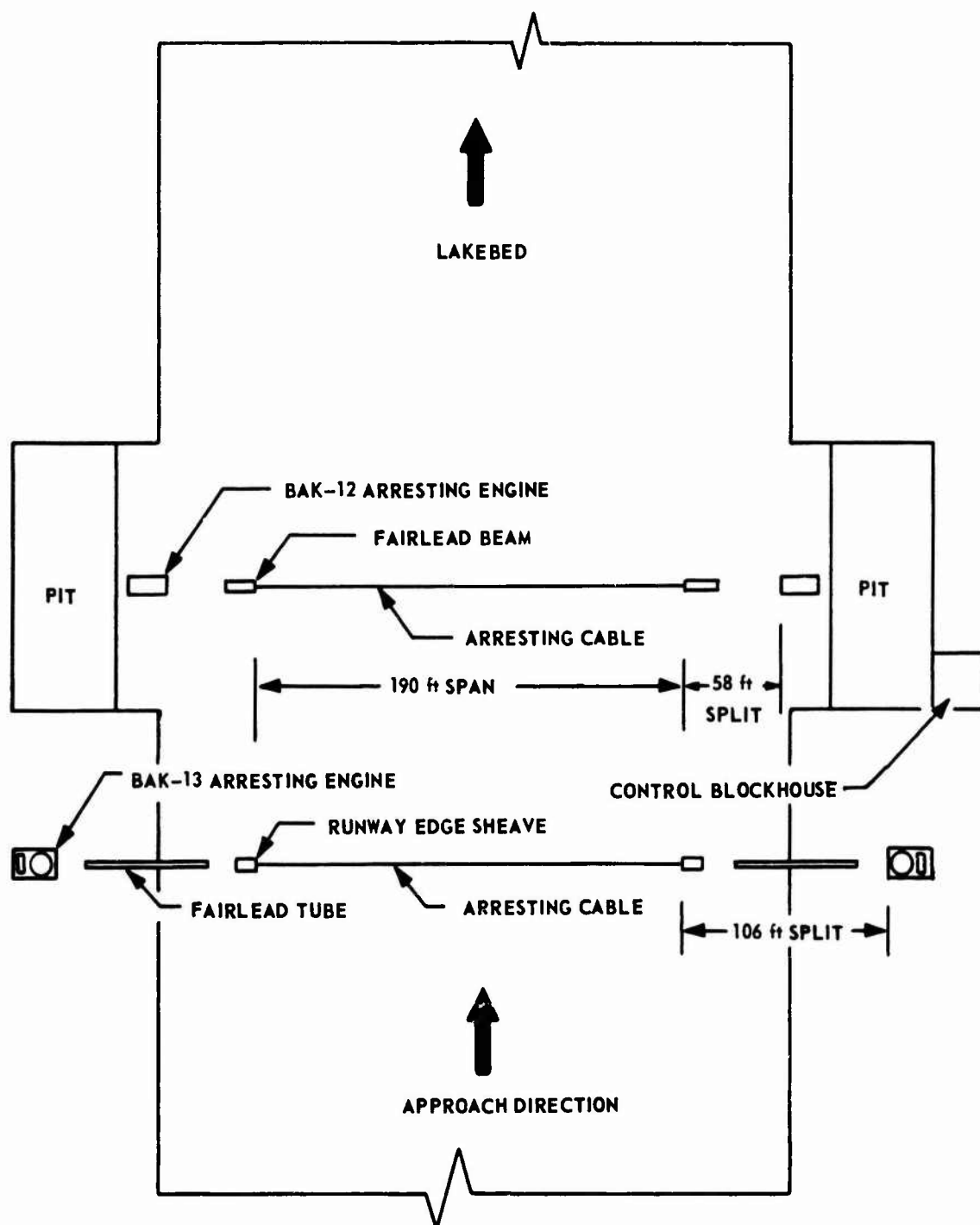


Figure 8 BAK-12 and BAK-13 A Test Installation



Figure 9 Polyurethane Rail



Figure 10 Standard Donut

NOT REPRODUCIBLE

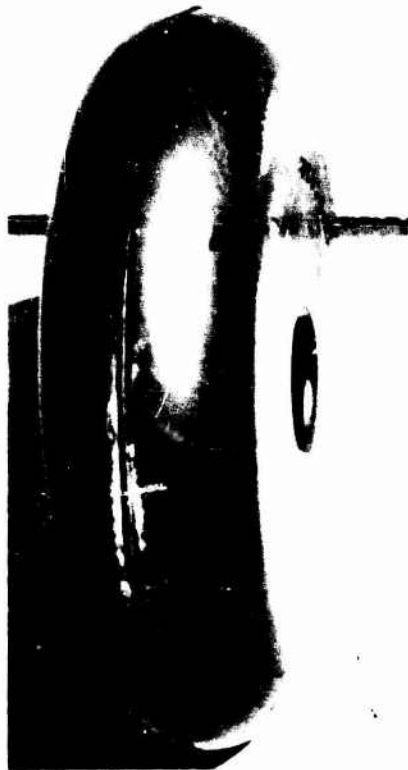


Figure 11 Heavy Duty Donut

TEST INSTRUMENTATION AND PHOTOGRAPHIC SUPPORT

Aircraft and arresting system parameters were permanently recorded on magnetic tape. An Inter-Range Instrumentation Group-Frequency Modulation (IRIG-FM) instrumentation system was employed for this purpose. An oscillograph provided quick-look data immediately after each test. It allowed immediate review to determine if all parameters were being recorded and that hookloads and tape tensions were not exceeding their design limits. Quick-look data was also used for primary data reduction. The aircraft was instrumented for axial hookload, dashpot load, vertical hook position, and lateral hook (side) load. Aircraft parameters were telemetered to the arresting gear test ground station and recorded on magnetic tape with the arresting gear parameters.

The arresting systems were instrumented to record the following parameters:

BAK-12	BAK-13
Tape tension	Tape tension
Brake pressure	Tape payout
Tape payout	Reel revolutions
Tape reel revolutions	Dynamometer fluid temperature
	Dynamometer fluid return line temperature
	Dynamometer fluid pressure
	Dynamometer fluid return line pressure

Three-sheave tensiometers were used to measure tape tensions. Pressure transducers were used to measure brake pressure (BAK-12), fluid pressure in the BAK-13 reservoir, and return line pressure (BAK-13). Resistance temperature probes measured fluid temperatures (BAK-13). Tape payout was measured by an interrupted light beam which counted sheave revolutions. Arresting gear parameters were hard-wired to the instrumentation ground station and recorded on magnetic tape with the aircraft data.

A Chrondek Electronics, Inc. photoelectric velocity measuring system recorded actual aircraft engagement speed.

In addition to the recorded data, photographic data and documentation was obtained for all tests. Coverage for the tests was obtained using two 16mm, 250 frames per second (fps) hand-pan cameras; one 16mm, 48 fps hand-pan camera; three 16mm, 1,000 fps remotely operated cameras; and one 16mm, 64 fps remotely operated camera mounted on the aircraft wingtip. The handpan cameras provided total coverage of the engagement and arresting hook dynamics. The remaining remotely operated cameras provided data on cable dynamics, hook impact, and hook dynamics.

TEST PROCEDURES

The A-7D aircraft was tested at gross weights of 25,000, 33,000, and 42,000 pounds. These weights were chosen as representative of an aircraft at minimum landing, medium, and maximum gross weights, respectively.

Sixty-eight test engagements were made by taxiing the aircraft into the arresting system, and six tests were approach end engagements. For the ground taxi engagement, the hook was lowered approximately 800 feet from the arresting cable, and engine power was reduced to idle just prior to the engagement. Pilots were requested not to use brakes or aircraft controls during runout for most tests. For the approach end engagement, the aircraft touched down before reaching the arresting gear and made the engagement. The purpose of the approach end engagements was primarily to validate the procedures stated in the Flight Manual (reference 1) and to achieve higher engagement speeds.

Fifty test engagements were made at the arresting systems centerline. Twenty-four test engagements were made off center at distances of 35 and 50 feet from the centerline of the arresting system. The off-center tests were accomplished to determine if the A-7D developed any serious control problems from asymmetric loading placed on the aircraft by the arresting gear.

TEST AND EVALUATION

A summary of the data is presented in appendix I for the 74 tests conducted during this program. Deficiency Reports (DR's) have been or are being submitted on these tests as was done on all A-7D Category II Follow-On tests. Copies of DR's submitted for action and an explanation of the DR system are contained in appendix II.

OPERATIONAL ANALYSIS

Test results indicated that the A-7D Flight Manual (reference 1) procedures generally were satisfactory, but further explanation and minor procedural changes were considered necessary.

Approach End Engagements

Six approach end engagements were attempted: 3 with a 25,000-pound aircraft and BAK-12 using heavy duty donut cable supports, and 3 with a 33,000-pound aircraft and BAK-13 using rail type cable supports. The procedures used were those published in the A-7D Flight Manual (reference 1). Once the aircraft had landed, the approach end engagement ceased to be different from other barrier engagements discussed under Centerline and Off-Center Engagements.

All BAK-12 approach end engagements were successful. One BAK-12 engagement was made with the aircraft nose gear approximately one and one-half feet in the air. The nose of the aircraft did not drop violently, but was lowered in much the same manner as during a normal landing in which the nose would be allowed to continue to lower to the runway instead of being held up for aerodynamic braking. The gradual increase in the deceleration force of the BAK-12 during the first 200 to 300 feet after engaging the arresting gear did not cause an undesirably high rotation rate. One engagement was intentionally made with the touchdown right at the arresting cable. A comfortable engagement was made at 165 knots. (The A-7D landing gear has been designed for carrier type landings.)

Two BAK-13 approach end engagements were successful and one resulted in a missed engagement (see the Hook Bounce/Missed Engagements section for the cause of missed engagements). BAK-13 deceleration forces were applied more rapidly than those of the BAK-12. It is very doubtful that any aircraft damage would result if the aircraft nose gear was not down on the runway for a BAK-13 engagement; however, it is desirable to have all three landing gear on the runway if possible.

The A-7D Flight Manual recommended 300- to 500-foot touchdown aiming point appeared to be satisfactory in most instances. If a smooth flare

to a gentle touchdown is desired, there would be sufficient room for this to take place. When planning for an actual approach end engagement and aircraft directional control is at all doubtful, the aircraft touchdown should be close to the arresting cable. Based on these tests, changes are recommended for the Approach End Engagement section as noted at the end of the Operational Analysis section. (R 1)¹

Brake application of a severity great enough to cause blown tires must be avoided as discussed in the Aircraft Braking section of this report.

Centerline Engagements

The deceleration forces encountered during all centerline engagements were smooth. All engagements were made with the aircraft engine throttle at idle and with the brake antiskid system on for all approach end engagements and some ground taxi tests. Flaps were set at 25 degrees for all ground taxi tests and 25 or 40 degrees for the approach end engagements. Nosewheel steering was engaged on six of the test engagements. Pilots used slight pressure on the rudder pedals to steady the aircraft on center. No significant steering corrections were input. These procedures reduced aircraft yaw and resultant lateral displacement during the arrestment. Lateral displacement was held to one foot or less on these tests. On tests where nosewheel steering was not used, the aircraft tended to yaw five to seven feet. The maximum lateral displacement which occurred was 23 feet. Some lateral displacement could have resulted from the crown in the test runway and crosswind components. Nosewheel steering or differential braking was not necessary for on-center engagements. Aircraft roll and yaw tendencies were slight to non-existent and caused no pilot difficulties.

Off-Center Engagements

Upon initial contact of the cable during off-center engagements, the aircraft tail was pulled toward the runway centerline. This produced a rolling motion in the same direction. The motion then reversed and a combination of yaw and roll oscillations (fishtailing and wing rock) continued for two to three cycles after which the motion damped out. The aircraft then proceeded to roll out smoothly and continued to steer away from the centerline. Aircraft skidding along the runway was experienced. A pilot unfamiliar with engaging aircraft arresting systems in this aircraft may be surprised by this motion unless he is aware of this characteristic.

For the BAK-12 system, the amplitude and onset rate of the yaw/roll oscillation was lower at an aircraft weight of 42,000 pounds than at 25,000 pounds. The BAK-13 produced a yaw/roll oscillation of greater severity at 42,000 pounds. The motion damped out after two cycles at 25,000 pounds and after two and a half cycles at 42,000 pounds. The yaw/roll onset was less severe for the BAK-12 than the BAK-13 and was not considered severe except for engagements of the BAK-13 at 50 feet off-center. Yaw from off-center engagements on the BAK-13 was greater than corresponding engagements on the BAK-12.

¹Numbers indicated as (R 1), etc., represent the corresponding recommendation numbers as tabulated in the Conclusions and Recommendations section of this report.

Total aircraft lateral displacement due to yaw from the line of engagement was greater for the 50-foot off-center engagements than for the 35-foot off-center engagements. This was true for both the BAK-12 and BAK-13. Lateral displacement data for on- and off-center engagements are shown in appendix I. On the majority of tests, displacement was 15 feet or less. Nosewheel steering had to be used on 50-foot off-center engagements in excess of 100 knots to prevent the aircraft from gradually veering off the runway. The test arresting gear installations were for 190-foot runway spans. For wider runway spans, similar off-center engagement distances will result in less displacement and will be more easily controlled. The displacement can be controlled by the pilot without difficulty with nosewheel steering. However, the A-7D Flight Manual does not warn the pilot that nosewheel steering will be inoperative if the engine is shut down. The information found at the end of the Operational Analysis section of this report should be included in the Flight Manual as noted at the end of the Operational Analysis Section. (R 2)

Hook Extension

The specifications as stated in reference 4 indicate that the arresting hook extends fully in $4 + 1$ seconds. Four A-7D aircraft used in the A-7D Category II FSEP were tested and compared to these specifications. The average time for the arresting hook to extend to ground level (approximately 35 degrees travel) was 2 seconds. The actual extension to ground level time will depend on the aircraft attitude and height above the runway at the time. This response time is sufficient for operational arrestments which are, of course, anticipated. However, when an emergency condition evolves, the aircraft will travel a great distance in the time required to extend the hook, i.e., at 130 knots it would travel 440 feet in 2 seconds or 880 feet in 4 seconds. To insure a high probability of success for emergency arrestments, an arresting hook response time of one second or less is desirable.

The A-7D Flight Manual (reference 1) presently states that the arresting hook is to be lowered 2,000 feet prior to reaching the arresting cable. Based on these tests, this minimum distance is greater than necessary even for the relatively slow A-7D hook extension. The Flight Manual should be changed to advise the pilot to extend the hook at least 1,000 feet prior to reaching the arresting cable. (R 2)

Stores Jettison

Both the BAK-12 and BAK-13 arresting systems have sufficient energy absorbing capacity to arrest the A-7D at any operational gross weight. For approach end type engagements, it is desirable to reduce gross weight as much as practicable prior to the actual engagement; however, the jettison of stores is not necessary for the BAK-12 or BAK-13 arresting systems. The decision as to whether or not stores should be jettisoned prior to an emergency arresting gear engagement is dependent upon the nature of the stores and the pilot's evaluation of the situation, including energy limitations for lower energy arresting systems included in the Flight Manual.

Aircraft Braking

The chances for successful arrestments are greatly reduced by tire failure (blowouts). The rim of the affected wheel may snag or damage

the cable, thus causing cable failure or a missed engagement. The Flight Manual should state that brake application of a severity great enough to cause tire blowouts must be avoided when an arresting system engagement is anticipated. However, an approach end engagement is desirable for landing emergencies involving a previously blown tire (e.g., a blown tire on takeoff. (R 1, R 2)

Rollback

On three of the higher energy arrestments with the BAK-12, stored purchase tape energy in the form of an elastic load buildup caused the aircraft to rollback at the end of the arrestment. No rollback occurred with the BAK-13 at any A-7D aircraft weight. On test 54 at an aircraft weight of 41,560 pounds and engagement speed of 163 knots using the BAK-12, a maximum rollback of approximately 80 feet was experienced. Aircraft braking was not used at the end of the arrestment. The major problems of rollback are the possibility that an aircraft tire could pass over the tape end connector which could cause a blown or damaged tire, or the hook could snag an expansion joint or other runway irregularity resulting in a damaged hook or hook subsystem. Rollback can be controlled if brakes are available and lightly applied at the end of the arrestment. Although the aircraft pitched up slightly when braking was applied during rollback, the tendency for the aircraft to tip backwards onto the tail was slight and easily controlled. The most aft aircraft cg tested was 31.1 percent mean aerodynamic chord (MAC). Thus, the Flight Manual should state that aircraft rollback should be expected with high energy BAK-12 arrestments and that light braking can be used to control rollback. (R 1)

Maximum Arresting Hook Engagement Speed

The maximum engagement speeds at which the A-7D was tested were 165 knots at 25,000 pounds, 167 knots at 33,000 pounds and 164 knots at 42,000 pounds. These speeds approach or exceed normal takeoff and landing speeds at the given weight conditions. The tire limit speed was 174 knots. Based on extrapolation of data from these tests and from data contained in references 5, 6, and 7, the aircraft arresting hook, the standard or extended runout BAK-12's, or the BAK-13 will accept engagements up to the theoretical 190-knot limit of the arresting system (with the exception of possible damage to the aircraft arresting system snubber discussed in another section of this report). Such high speed emergency engagements may be required due to conditions resulting from battle damage or other extreme conditions. The tire limit must be considered in conjunction with probable cable damage/failure which will result if a tire is blown prior to the engagement. If such engagements are attempted, all possible precautions must be taken to avoid tire failures prior to the engagement. (R 1, R 2)

Aircraft Disengagement

The aircraft was disengaged from each arresting system by first stretching the nylon purchase tapes with the application of aircraft power while the arresting cable was still in the hook. Aircraft brakes were then applied and engine power was reduced to idle. Then, the stretched tapes were allowed to pull the aircraft backwards (by releasing aircraft brakes) until the hook was free of the arresting cable. Disengagement from the BAK-12 required that the arresting engines brakes be locked prior to stretching the tape. Disengagement from the BAK-13,

however, required that the tapes be pulled from the arresting engines to their full length by the aircraft before they could be stretched.

The A-7D Flight Manual should contain procedures for disengagement as noted at the end of the Operational Analysis section. (R 3)

Flight Manual Changes

The following are the recommended changes for the A-7D Flight Manual:

Recommendation 1 - Approach End Engagement

pp. 3-37 Add to Discussion:

There should be little concern if the touchdown point is close to a BAK-12 arresting system and/or the nose gear is not on the runway. The deceleration force of the BAK-12 arresting system is applied in a smooth increasing manner, which will cause the nose of the aircraft to lower to the runway in much the same way as during a normal landing. The motion is not violent. With BAK-13 type engagements, the deceleration force is applied more rapidly; therefore, it is best to have all three landing gear on the runway for engagement. The landing gear have been designed for carrier landings. For engagements less than 35 feet off-center, aircraft yaw and roll are minimal to non-existent. Rudder, aileron, and nosewheel steering may be required to maintain aircraft control on engagements over 35 feet off-center. Lateral displacement from off-center arresting gear engagements is toward the nearest runway edge.

The yaw is abrupt for the BAK-13, whereas the onset is more gradual for the BAK-12. The magnitude is approximately the same. The aircraft tends to skid in the opposite direction to the yaw (i.e., yaw right, skid left). The arresting cable itself tends to straighten the path of the aircraft after the initial yaw; however, use of aircraft controls and nosewheel steering will help the pilot maintain directional control of the aircraft path.

pp. 3-37 Add as Steps 5 and 6 and renumber the former Step 5 as Step 7:

5. If available use nose gear steering, flight controls, and/or brakes to maintain directional control.

WARNING

The chances for successful arrestments are greatly reduced by tire failures (blowouts). The rim of the affected wheel may snag or damage the cable, causing cable failure or a missed engagement. When an arrest-

ing system engagement is anticipated, braking heavy enough to cause blowouts must be avoided.

6. It is desirable to steer for center of arresting gear and make contact perpendicular if this can be done without any danger of losing aircraft control.

pp. 3-37 - Change the NOTE after the last step in Approach End Engagement to read:

The throttle may be inadvertently advanced due to deceleration forces on the pilot's body from engagements at higher speeds (over 130 knots).

pp. 3-39 - The NOTE on figure 3-10 of the Flight Manual should include the following:

3. High energy engagements may result in aircraft rollback. Rollback can be controlled by light braking at the end of the arrestment. Caution should be used to prevent the aircraft from tipping back on the tail by the use of too much braking.

Recommendation 2 - Abort/Barrier Engagement

pp. 3-4 - Add the following to the WARNING following step 1:

Nose gear steering will be inoperative if the engine is shut down.

pp. 3-4 - Change Step 3 as follows:

Change the 2,000 of Step 3 to 1,000.

pp. 3-4 - This WARNING should be included in the A-7D Flight Manual:

WARNING

The chances for successful arrestments are greatly reduced by tire failures (blowouts). The rim of the affected wheel may snag or damage the cable, causing cable failure or a missed engagement. When an arresting system engagement is anticipated, braking heavy enough to cause blowouts must be avoided.

Recommendation 3 - Arresting Gear Disengagement Procedures

BAK-12 Disengagement Procedures:

1. After ground personnel have locked the arresting engine brakes and clearance to apply power has been given, gradually advance throttle to 90 percent to stretch the arresting gear tapes.

2. Lock aircraft brakes and reduce engine power to idle.
3. Release brakes and allow stretched tapes to pull aircraft backwards.
4. When ground personnel signal that the hook is clear of the cable, retract arresting hook.

BAK-13 Disengagement Procedures:

1. After ground personnel have given clearance to apply power, taxi forward slowly to pull the arresting gear tapes out to their full length.
2. Gradually advance throttle to 90 percent to stretch the arresting gear tapes.
3. Lock aircraft brakes and reduce engine power to idle.
4. Release brakes and allow stretched tapes to pull aircraft backwards.
5. When ground personnel signal that the hook is clear of the cable, retract arresting hook.

A-7D SYSTEMS EVALUATION

Hookloads

A data summary for all testing is presented in appendix I. Maximum braking hookloads for the aircraft are shown as a function of engagement speed in figures 12 and 13. The definition of brake hookload is shown graphically in figure 14. The maximum brake hookload was primarily dependent upon the aircraft engagement speed for the 25,000- and 33,000-pound test weights and was relatively independent of the aircraft weight for both the standard BAK-12 and BAK-13. Extrapolation of these curves indicates that the hook load limits will not be exceeded within the arresting gear limit of 190 knots. Typical hookload versus runout curves are presented in figures 15 and 16. The runout distance at which the maximum hookload occurred was dependent upon the aircraft weight for each arresting system. At 25,000 and 33,000 pounds gross weight, the peak hookloads occurred at approximately 300 feet with the BAK-12 and approximately 200 feet with the BAK-13. During the 42,000-pound arrestments with the BAK-13, the maximum hookload was sustained over an interval extending from approximately 200 to 400 feet of aircraft runout. At 42,000 pounds gross weight with the BAK-12, hookload increased with aircraft runout in the braking region and "peaked out" near the end of the arrestment. This was typical for heavy weight arrestments. The aircraft energy was approaching the standard BAK-12 arresting gear design limit, and the system compensated by applying higher brake pressures until the aircraft stopped. The cam controlled valves on the arresting engines were programmed to increase brake pressure during the later phase of the arrestment in case the aircraft did not slow sufficiently. As compared to on-center tests, maximum brake hookloads for off-center tests appeared approximately the same for both the BAK-12 and the BAK-13 (figures 12 and 13).

A-7H HOOK EVALUATION TESTS
BRAKE HOOKLOAD PERFORMANCE

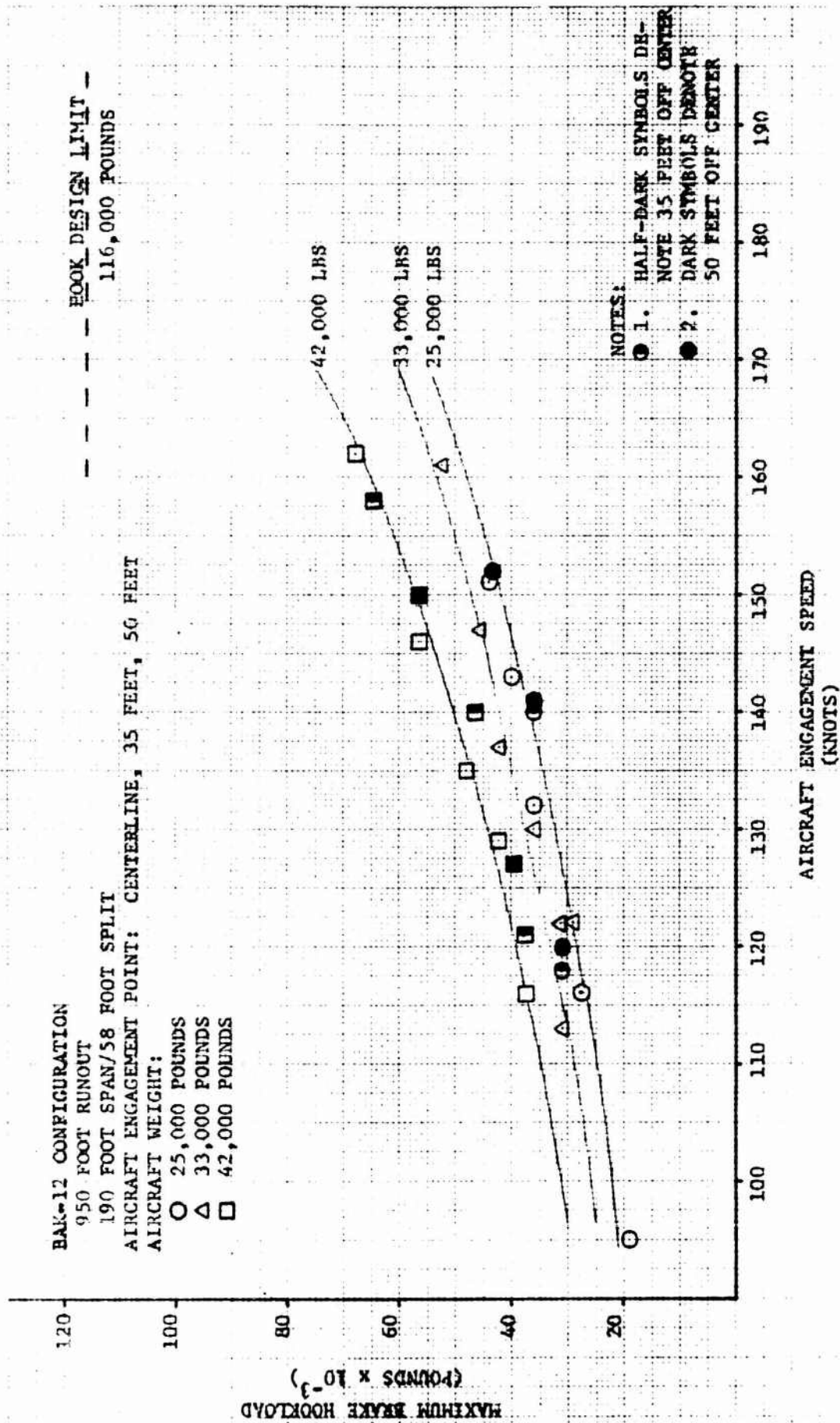


Figure 12 Brake Hookload Performance

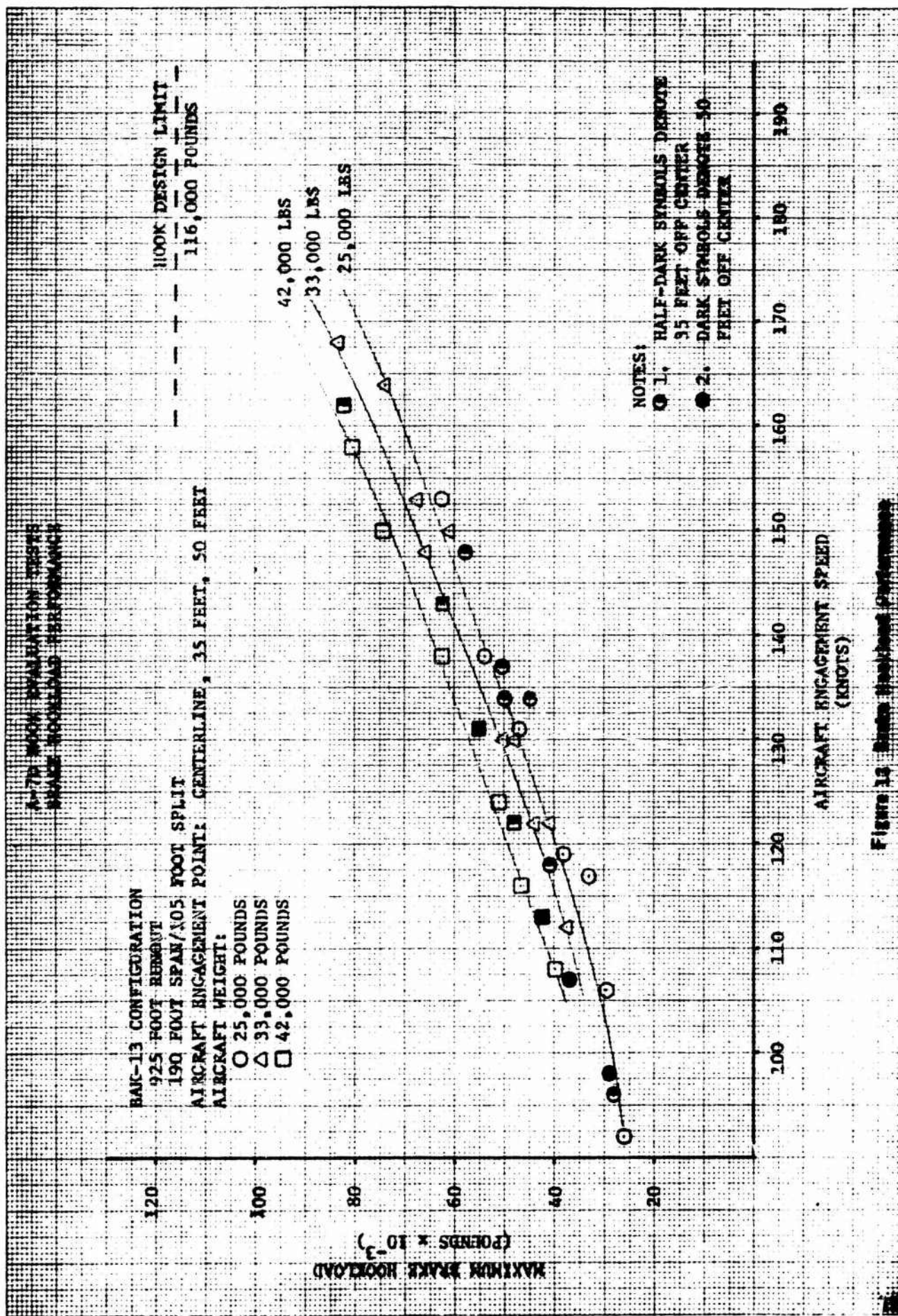
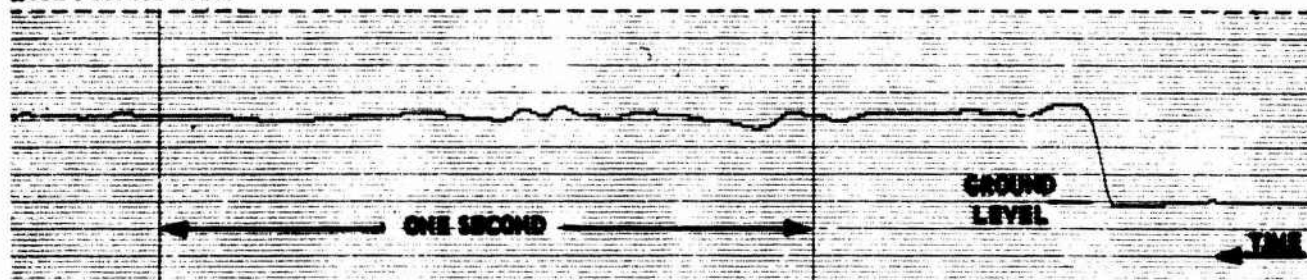


Figure 12. Brake Hookload Performance

Impact hookloads as defined on figure 14 increased with engagement speed and remained lower than braking hookloads, but were independent of aircraft weight. Impact hookloads reached a maximum of 48,100 pounds and were well below the design hook strength of the A-7D. A summary of all impact hookloads is shown in appendix I.

Test 21; 33,800 Pounds/129 Knots

Hook Position Trace



Hookload Trace

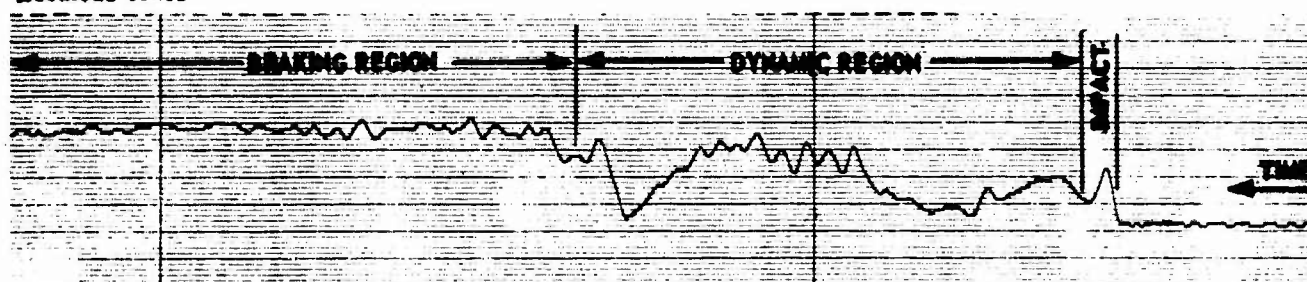


Figure 14 Typical Quick-Load Data Traces

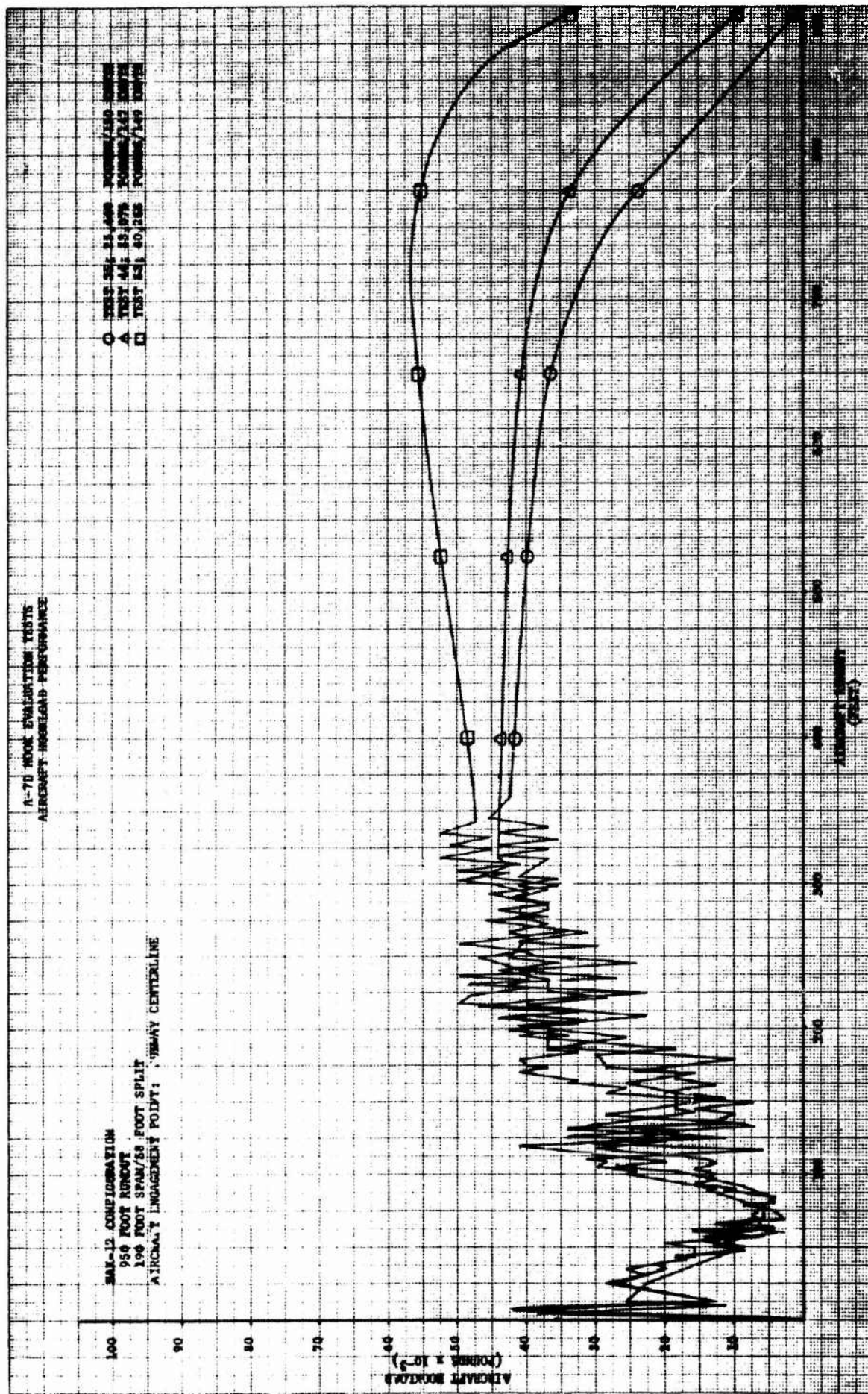


Figure 15 Aircraft Noise Performance

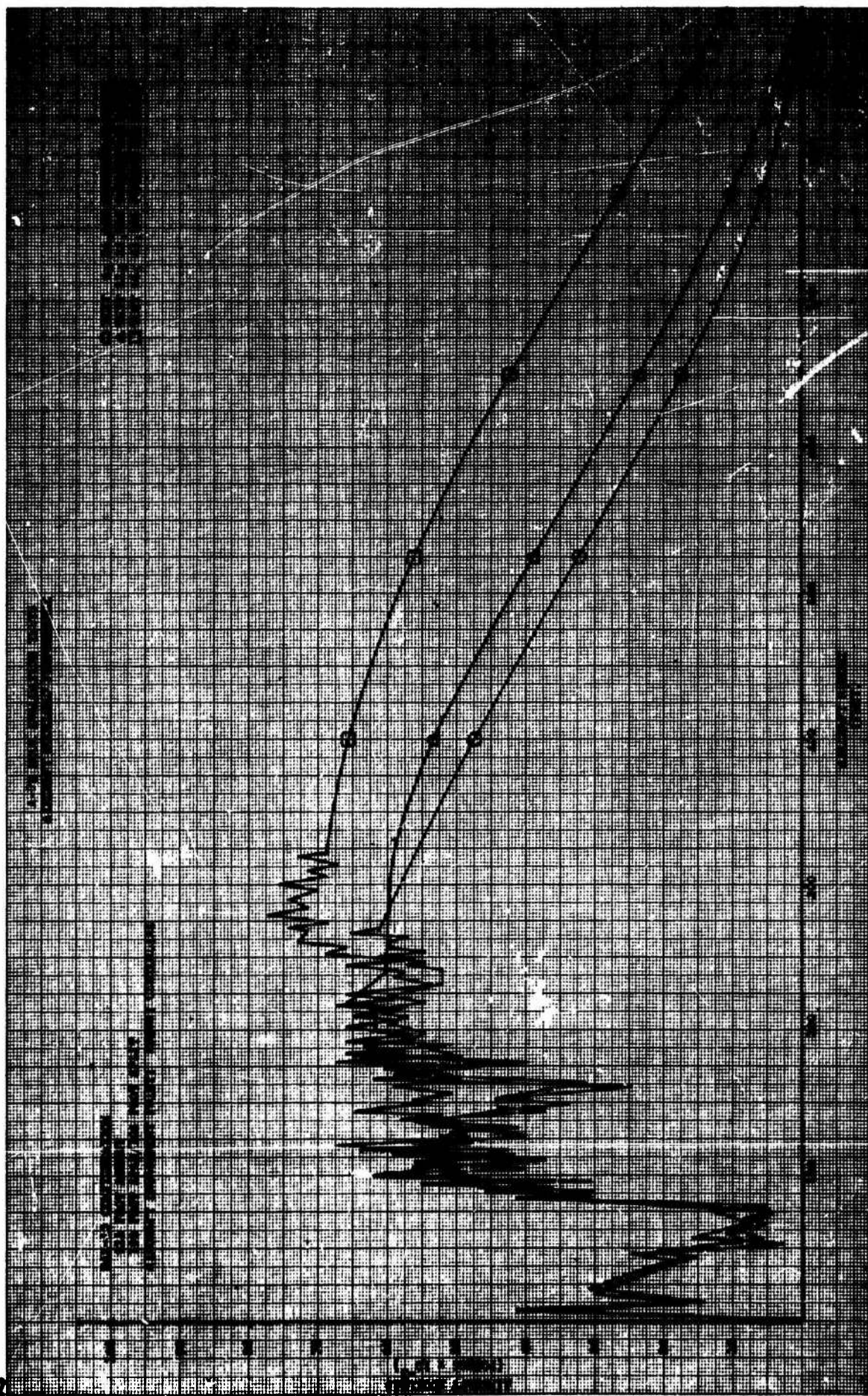
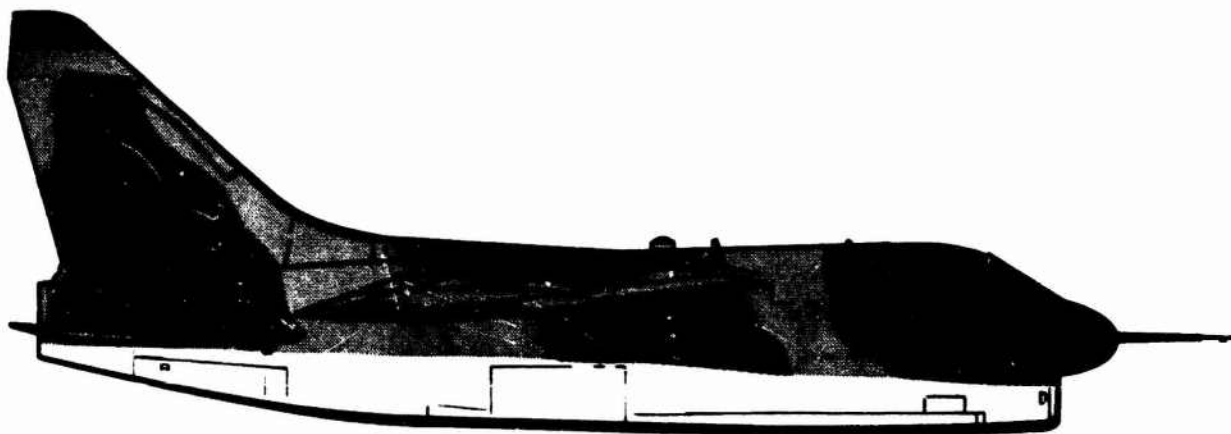


Figure 16 Aircraft Nocturnal Performance

Hook Actuator Snubbing Loads

The arresting hook was extended and retracted by a hydraulic/pneumatic system (figure 1). During an engagement, the actuating cylinder (actuator) and accumulator functioned as a hook snubber. The arresting hook actuator rod end was instrumented to measure the loads placed upon the actuator (appendix I). The rod end had a design limit of 21,500 pounds in compression and was the weakest structural part of the hook subsystem. Figures 17 and 18 show maximum snubber load versus aircraft engagement speed. Typical hook actuator assembly load traces of high speed engagements for the BAK-12/heavy duty donuts and the BAK-13/polyurethane cable supports are shown in figures 19 and 20. The highest loads always occurred at cable impact and the average snubber loads were slightly higher for the BAK-13.

The rod end load became a determining factor for high speed engagements. However, the design limit of the actuator was approached at all aircraft speeds. The design limit was approached or exceeded on 20 tests, and a maximum of 24,200 pounds occurred on one test at an aircraft weight of 33,000 pounds and an engagement speed of 165 knots. The actuator rod end load limit should be increased. A DR will be submitted.



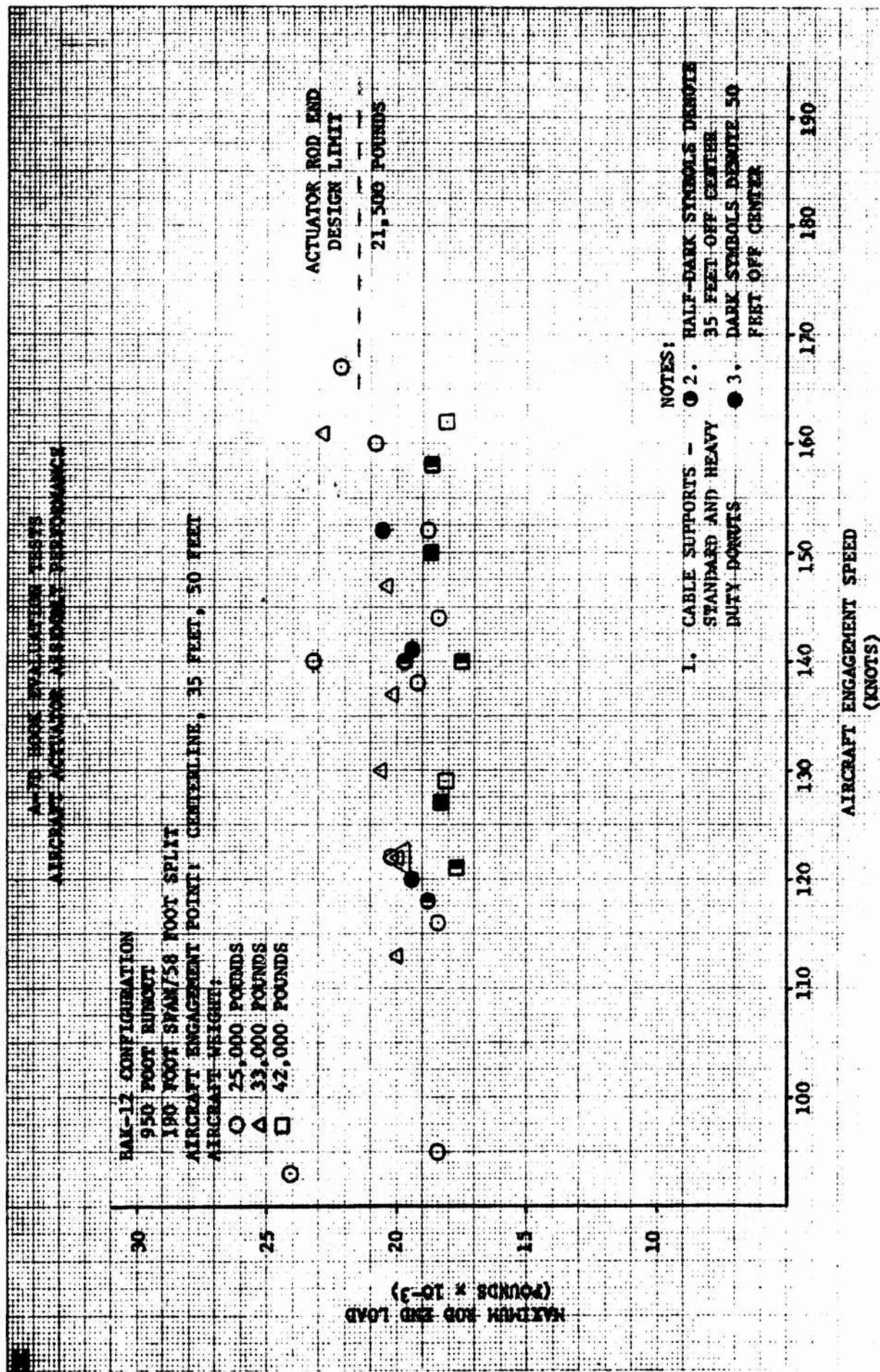


Figure 17 Aircraft Actuator Assembly Performance

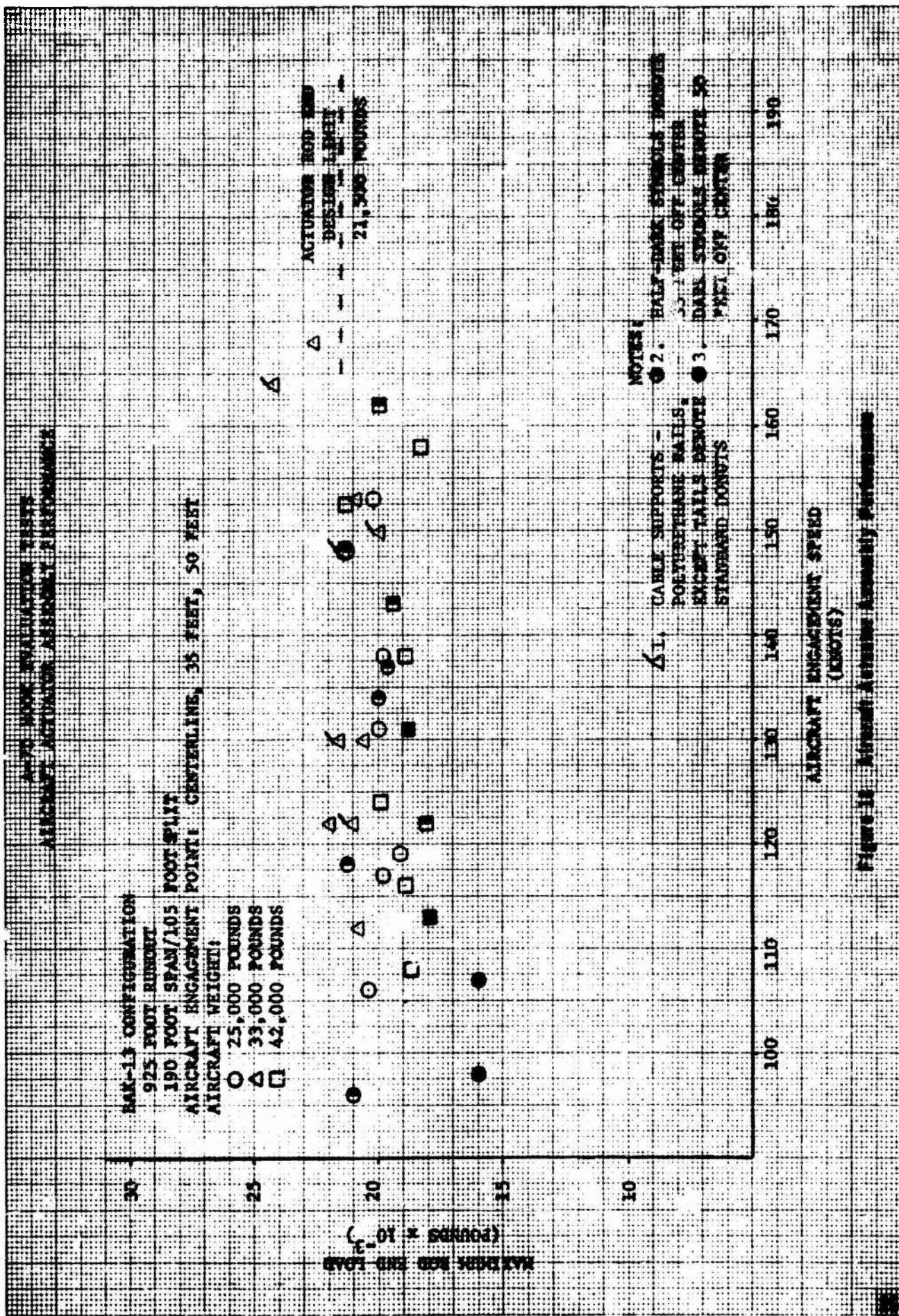


Figure 13 Aircraft Actuator Assembly Performance

Test 45; 32,750 Pounds/162 Knots

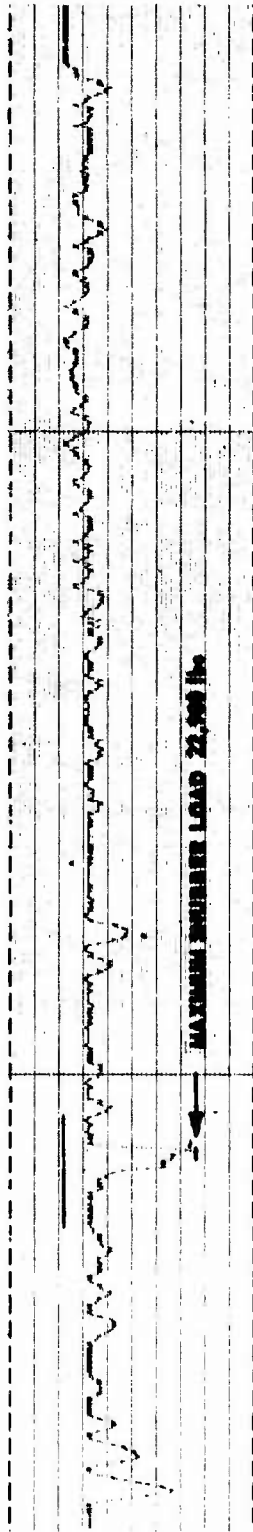


Figure 19 Neck Actuator Tests (Heavy Duty Dent Cable Supports)

Test 26; 32,740 Pounds/165 Knots

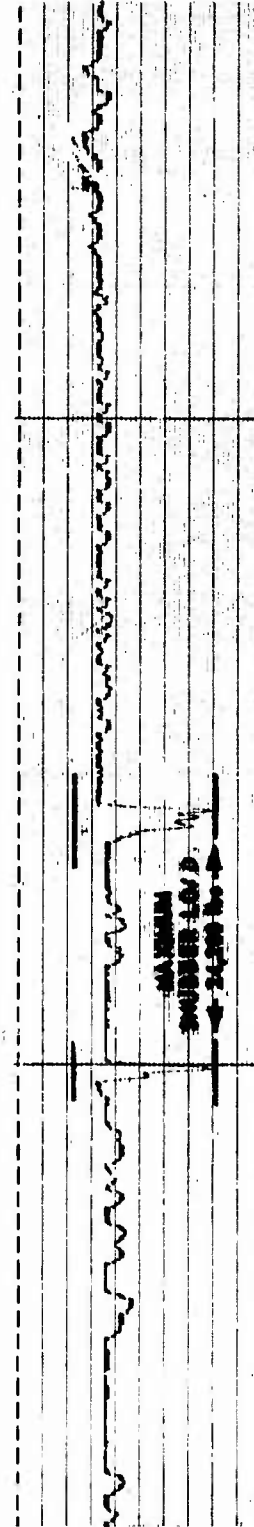


Figure 20 Neck Actuator Tests (Polyurethane Roll Cable Supports)

Hook Sideloads

Arresting hook sideloads were analyzed to determine the effects of asymmetric loadings on the airframe structure during on- and off-center engagements. These loads never exceeded the design limit of 36,650 pounds at the hook shoe, and inspections of the arresting hook after tests 26 and 50 showed no signs of damage resulting from excessive sideloads. Data on arresting hook sideloads is contained in appendix I.

Hook Bounce/Missed Engagements

The A-7D engaged the arresting cable in 70 of the 74 tests during this program (94 percent). This reliability is considerably lower than that of other Air Force aircraft equipped with stiff shank arresting hooks. Table II identifies the conditions of each missed engagement. The type of cable support used had a significant effect on the cable height at the time of the engagement. Three different types of supports were used and are discussed in a separate section of this report.

The nose of the shoe assumed an attitude above the runway surface which increased proportionally with the amount of hook rotation. In figure 21, the nose of the hook shoe is approximately 1 inch above the runway surface at 40 degrees (from an aircraft horizontal reference); at 70 degrees this increased to approximately 2-1/2 inches. This is shown graphically in figure 22. This poor attitude characteristic was caused by the shortness of the hook shank. The actual angle between the hook shank and the runway varied with aircraft pitch attitude, aircraft weight, and aerodynamic lift. Since the aircraft attitude was not measured, the absolute angle is not known. Generally, the angle decreased with speed; thus, the worst conditions were at light aircraft gross weights and high speeds. Figure 23 is a sequence of photos taken from the wing tip camera and shows the range of hook shank angles which occurred prior to a typical approach end engagement. The engagement was at 140 knots and a 25,000 pound aircraft gross weight. The hook shoe attitude problem was considered a significant safety hazard. DR No. F406-184 was submitted recommending that the hook shoe be redesigned so that the nose of the shoe stays on the runway surface, regardless of hook shank angle. Testing of any modified shoe is also recommended. (R 4)

The hook was also observed to oscillate in a twisting motion about its longitudinal axis. It could not be determined whether or not this twisting motion contributed to missed engagements.

Hook bounce was not a significant problem. It was judged to be light to moderate as the hook passed over the expansion joints on the test facility runway. Hook bounce height was estimated from high speed 16mm motion picture film taken by ground cameras (showing only the area approaching the cable). Hook bounce could also be detected from telemetered hook position data. The data discussed here is considered representative of the test program. However, due to film reading limitations and camera field of view, it is not all inclusive. Hook bounce was normally less than three inches. Out of 20 hook bounces estimated to be 3 inches or more at the nose of the hook shoe centerline, only one may have exceeded 6 inches, and 3 were greater than 5 inches. Tests on which the hook skips were noted were at aircraft speeds of 91 to 162 knots. Hook bounce height could not be correlated with aircraft velocity. However, the distance travelled with the hook off of the runway during the bounce

was a function of velocity for a given height. With the one stated exception above, the hook returned to the runway within 15 feet of aircraft travel in all cases, and over half recovered in approximately 10 feet or less. When the arresting cable was three to four inches above the runway, the effective hook skip distance above the arresting cable centerline was considerably less than when the cable was resting on the runway, thus reducing the likelihood of a missed engagement. However, as noted previously, the hook skip problem was aggravated by a nose-high attitude of the hook shoe.

Design holddown force on the hook was proportional to the amount of downward hook travel. At 40 degrees of hook travel the holddown force at the hook shoe was 370 pounds. At 70 degrees, the force declined to 200 pounds.

Table II

CONDITIONS OF MISSED ENGAGEMENTS

Test No.	Ground Speed (kt)	Cable Supports	Approximate Height of Arresting Cable (Centerline) Above Runway at Impact (in.)	Approximate Height of Hook Shoe Nose Above Runway at Impact (in.)
7	131	Rails	Cable on runway	1-1/4*
18	117	Rails	Cable on runway	1-3/4*
33	160	Standard Donuts	1	2-1/4*
74	157	Rails	Cable on runway	2-1/4*

*Hook was contacting runway at a nose-high attitude. Variation in hook shoe nose height was due to the different hook shank angles (figure 21).

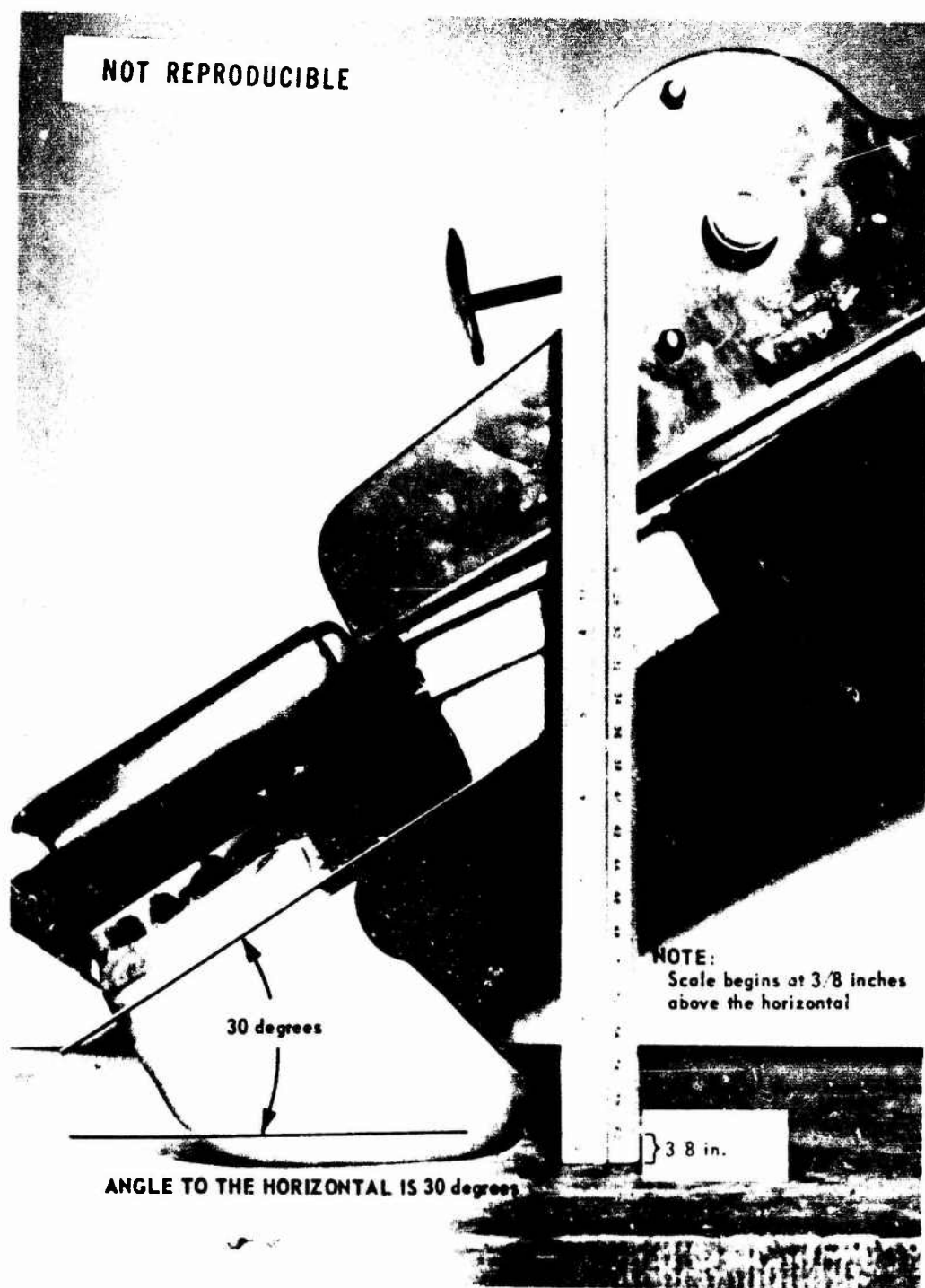


Figure 21 A-7D Hook Attitudes



Figure 21 (Continued)

NOT REPRODUCIBLE

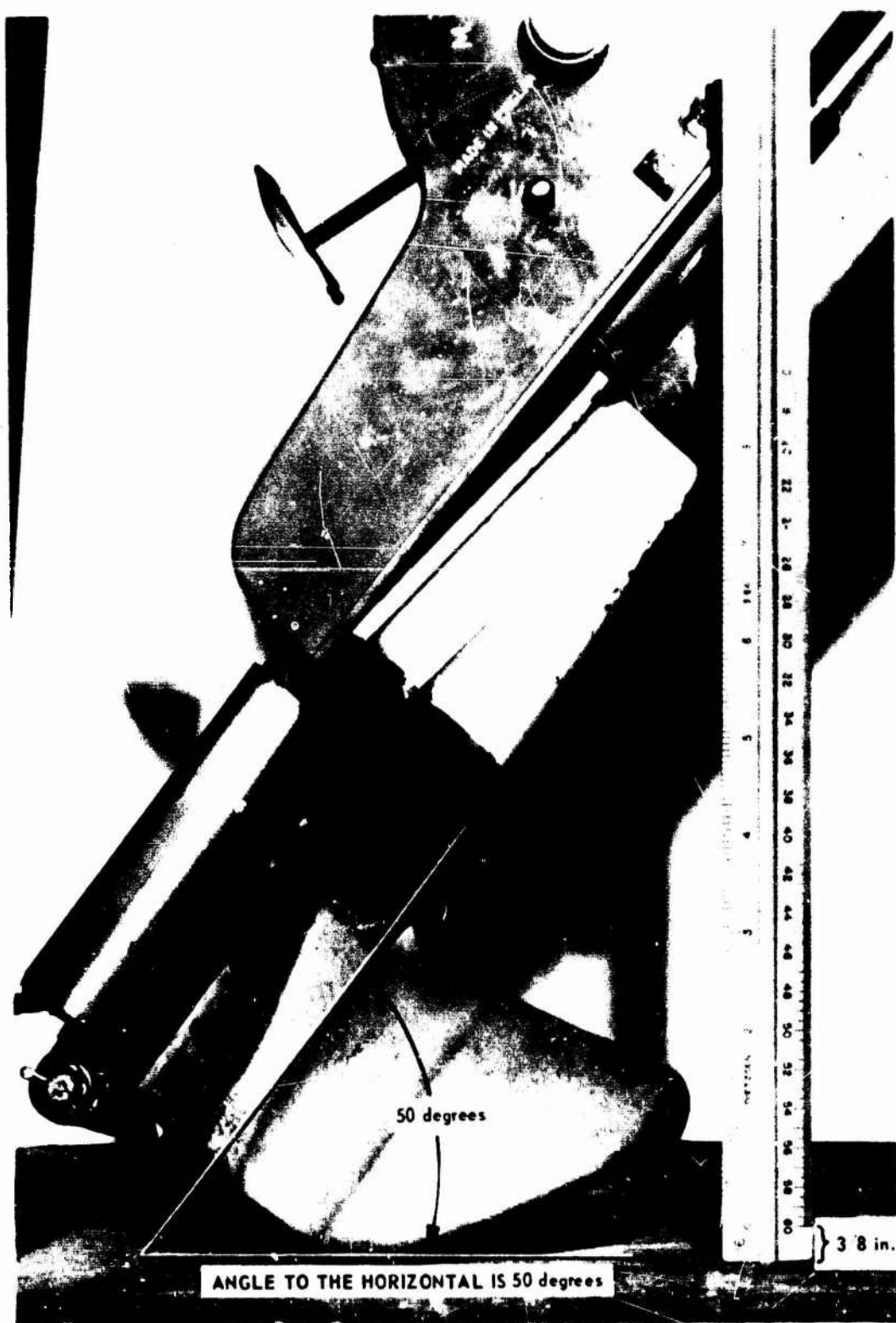


Figure 21 (Continued)

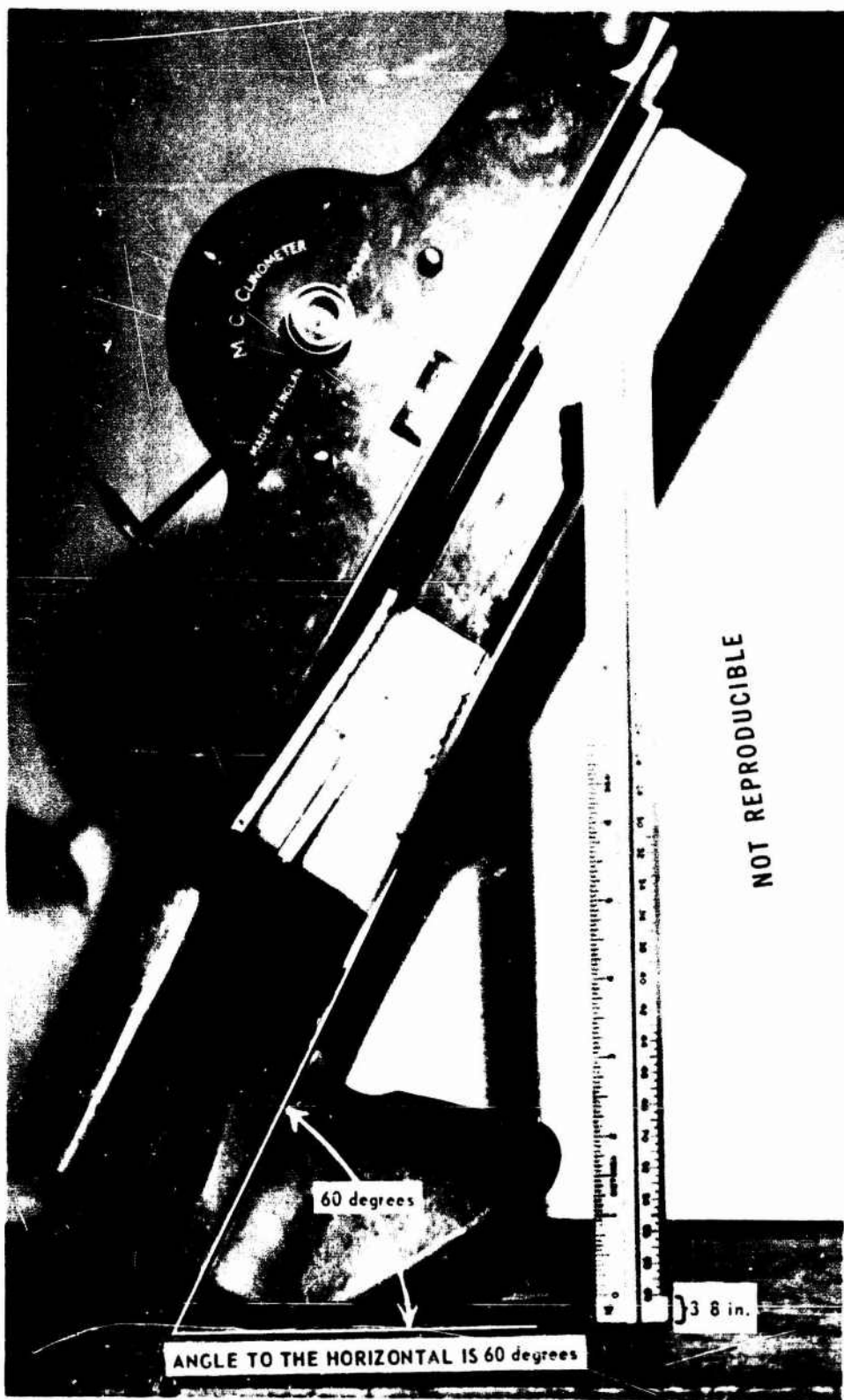


Figure 21 (Continued)

NOT REPRODUCIBLE

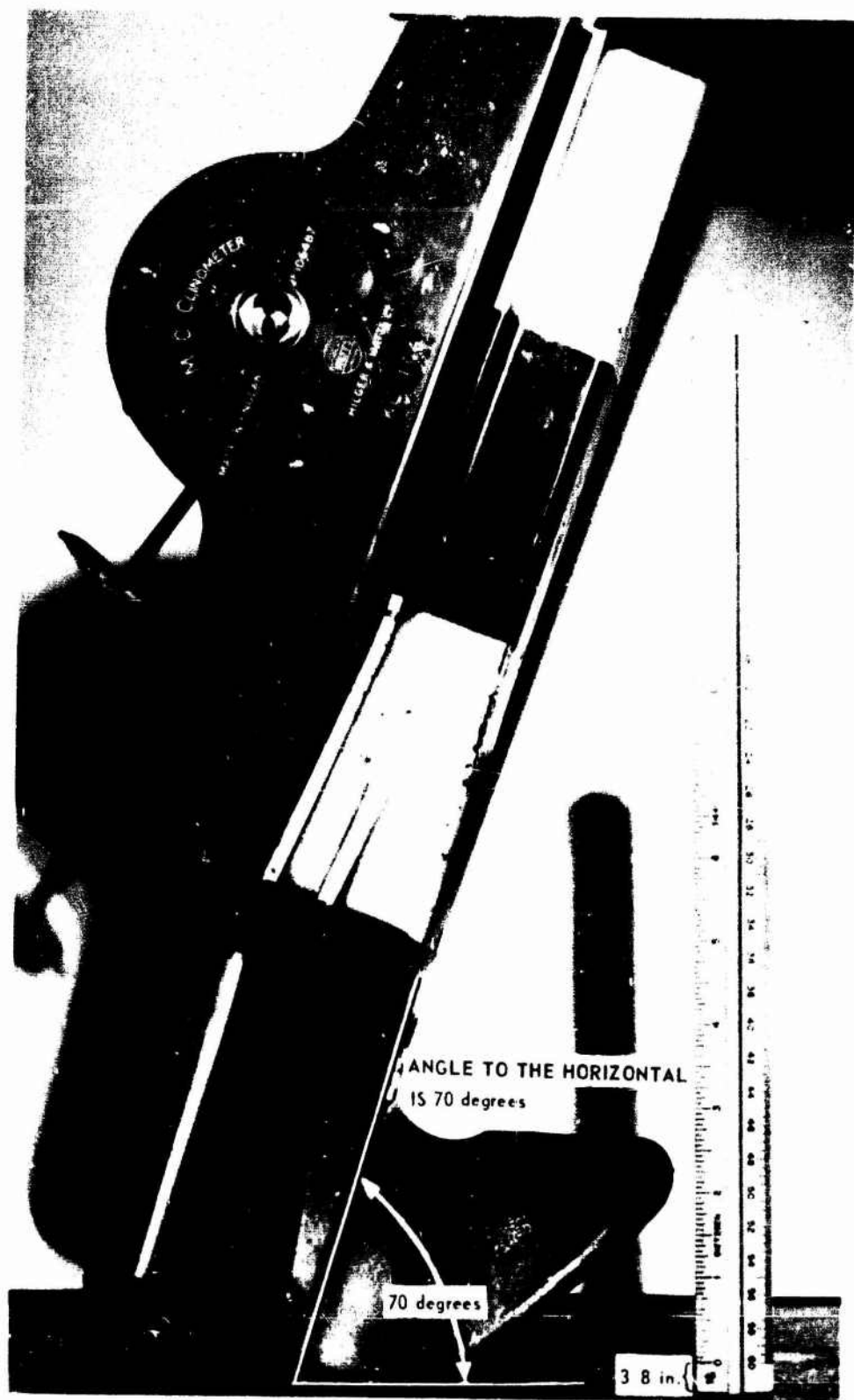


Figure 21 (Concluded)

BOOK SHOT ATTITUDE AT VARIOUS DEGREES OF BOOK TRAVEL

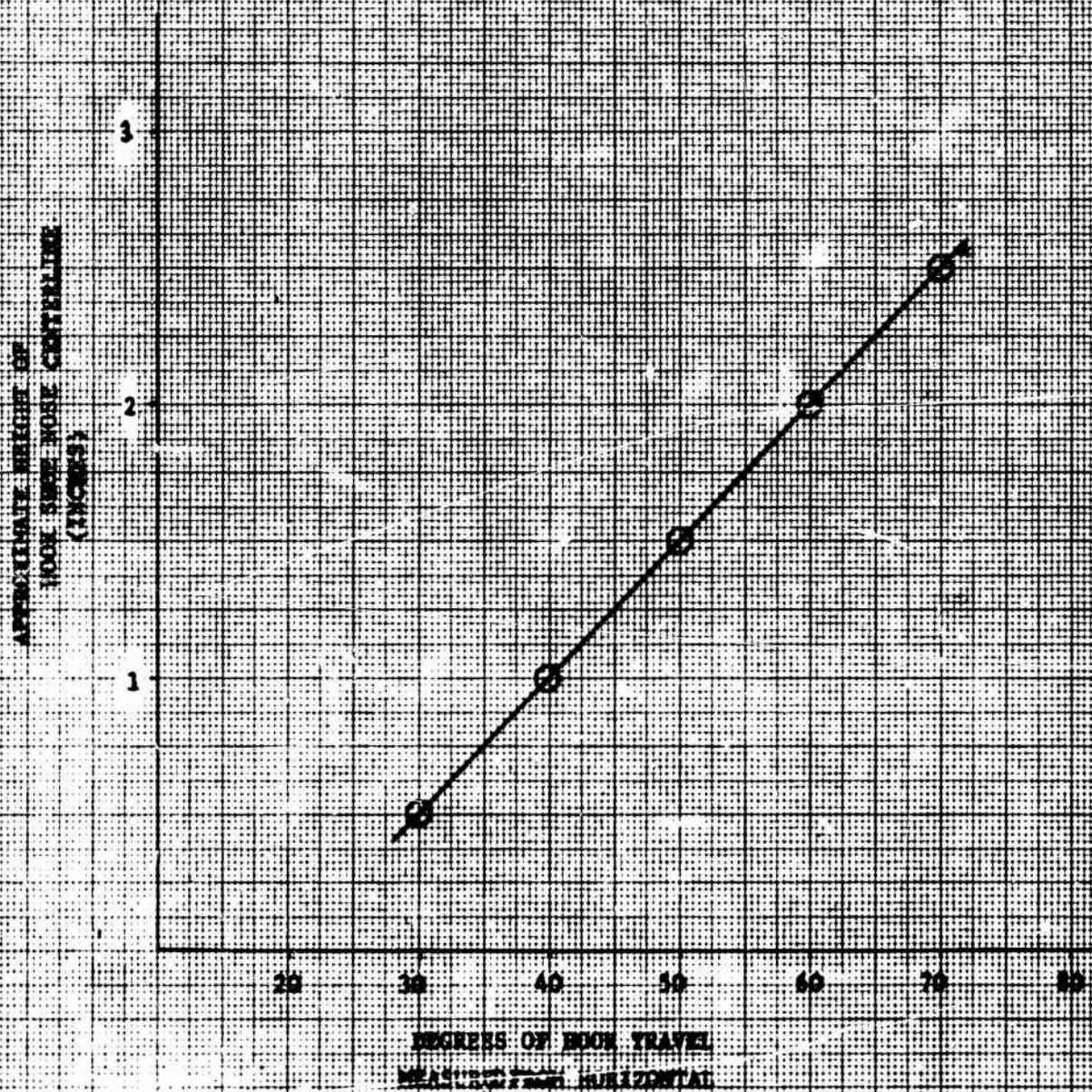


Figure 2

TEST 48; 24,940 lbs/140 KNOTS ESTIMATED
(Taken from wingtip camera)

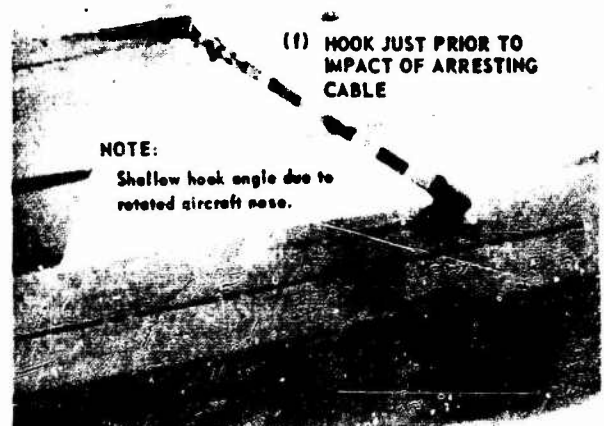
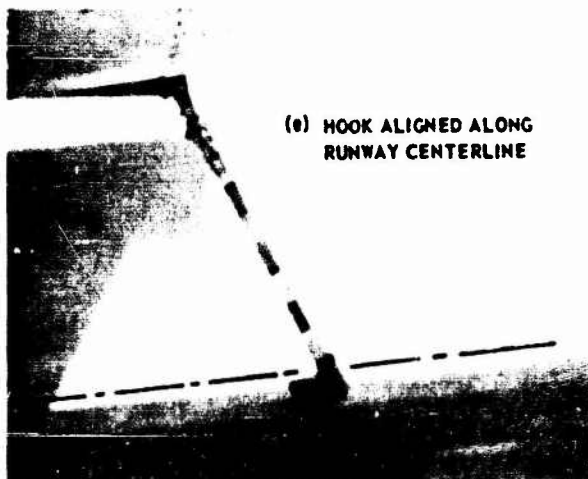
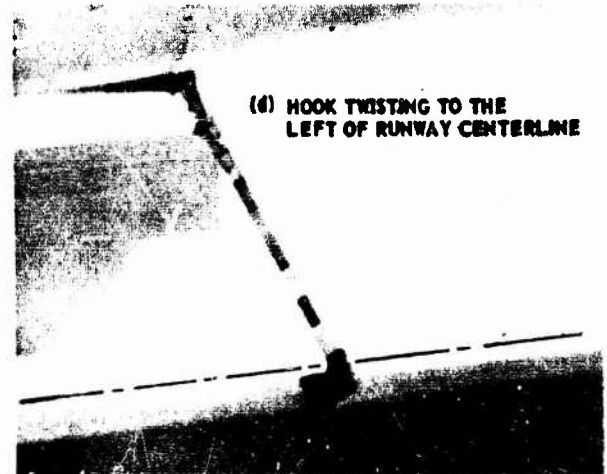
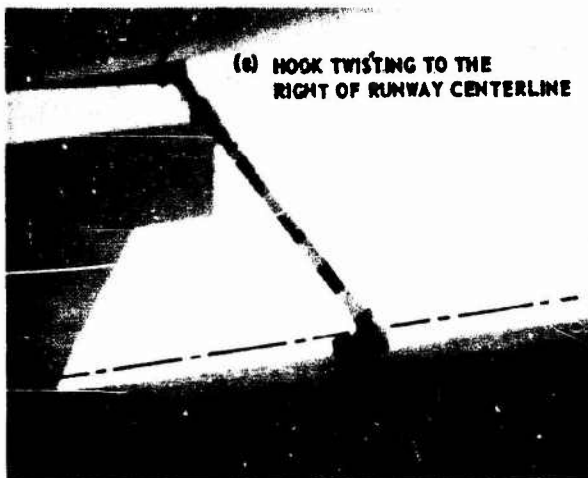


Figure 23 Hook Positions for a Typical Approach End Engagement

NOT REPRODUCIBLE

Hook Shoe Wear

Hook shoes had to be changed often throughout the test program. On early tests, the hook was extended so that the shoe slid on the concrete runway approximately 1,200 to 1,500 feet prior to the arresting cable. The first two shoes had to be replaced after three test engagements each as the bolt attaching the hook shoe to the hook shank was worn approximately halfway through the head. To get more test engagements from each hook shoe, the arresting hook was extended at approximately 500 to 1,000 feet from the arresting cable. The hook shoes used in this way averaged from 5 to 7 engagements before replacement was required. On heavier weight tests in which the hook shoe contacted the runway at the nose, hook shoes lasted for an average of 12 engagements. The necessity for frequent replacement of hook shoes in an operational environment could produce a heavy logistics requirement. Hook shoe wear presents a potential safety hazard in that if either a new or a worn but serviceable shoe were left in contact with the runway for long distances, it could fail on engagement. These conditions could occur if the pilot extended the hook very early in the arrestment or if an approach end engagement was missed and an engagement of a subsequent arresting system (either midfield or over-run) was attempted. The A-7D arresting hook shoes should be redesigned to reduce hook shoe wear. Correction of the hook shoe attitude problem may correct this. A DR will be submitted.

Aircraft and Hook Bumpers

The aircraft bumper and uplock mechanism were found to be structurally inadequate for engagements at speeds in excess of 150 knots. On test 26, at an engagement speed of 165 knots, the hook uplock mechanism, which was part of the aft belly pan assembly (P/N 216-40040-2) was damaged. Analysis of data film indicated that cable dynamics during the arrestment drove the hook upwards into the aircraft bumper and hook uplock. The hook could not be locked into the up or stowed position after the test. The impact tore the uplock mechanism from its mountings and cracked a skin panel in the immediate area. Two pins (P/N 215-44454-2) in the uplock mechanism were also bent from the impact. Damage also occurred on subsequent tests. It was noted after test 50 that the aircraft bumper would not drop into position when the hook was extended. This damage was believed to have been due to previous high speed engagements. The aircraft bumper and uplock mechanism was disassembled and examined. A bushing was binding, and the two pins that were bent after test 26 had been bent again. These were not serious problems since operational and most emergency arrestments of the A-7D will be at speeds below 150 knots where damage to the uplock mechanism was not experienced.

The hook bumper (P/N 215-44310-1) tore loose from the hook on several tests. The bumper was designed to cushion impact between the hook and aircraft during an arrestment. Inspections indicated that the rubber cushion had separated from the steel mounting plate. An improved hook bumper (P/N 215-44404-1), installed on A-7D No. 75 and subsequent, was obtained and evaluated beginning with test 44. The improved hook bumper proved to be superior and more reliable than the original bumper. However, the improved hook bumper was lost during test 74. Figure 24 shows the lower mounting plate which remained with the arresting hook. The mechanism of failure is unknown. Further investigation should be made to determine suitability of this hook bumper for operational use. (R 5)



Figure 24 Lower Mounting Plate of Improved Hook Bumper after Test 74

Aircraft Tires

Figure 25 shows typical tire damage due to repetitive arresting cable rollover at heavy aircraft gross weights. Aircraft main gear tires were very susceptible to cuts from the arresting cable and foreign objects, and they had to be changed approximately every five tests. After further engagements, the condition deteriorated to the point that large sections of tire tread could be peeled from the tire casing. Heavyweight engagements also produced very rapid tire deterioration and made frequent tire changes necessary. In an operational environment, in which runways have multiple arresting systems spaced along their entire length, cable rollover at both low and high speeds is inevitable during normal takeoffs and landings. Therefore, frequent tire damage due to cable rollover in normal operational use should be expected. The A-7D tires should be im-

proved to reduce their susceptibility to damage due to cable rollover. The appropriate maintenance manuals should contain a statement which will require frequent inspections of A-7D tires. A DR has been submitted.



Figure 25 Typical Tire Damage due to Cable Rollover

ARRESTING SYSTEMS EVALUATION

BAK-12

The standard BAK-12 arresting system performed satisfactorily for all tests, and the energy absorbing limit exceeded the maximum which could be generated by an A-7D aircraft. The engagement envelope investigated is shown in figure 26. The maximum hookloads imposed on the aircraft are shown in figure 12. Maximum average tape tensions for the standard BAK-12 are shown in figure 27 for centerline, 35-, and 50-foot off-center engagements. As noted previously, the maximum loads occurred during the braking phase of the arrestment as defined in figure 14. All tape loads resulting from the A-7D arrestments were well within the operating limit. Data on maximum hydraulic brake pressures, initial maximum tape and hook impact loads, aircraft runout, etc., can be found in appendix I.

Data from these tests was compared with data in reference 5. The data agreed reasonably well. Typical characteristic traces of hook and tape loads versus time are shown in figures 28 and 29. These tape load time history traces are for the same tests shown in figure 15.

BAK-13

The BAK-13 used for testing in this program was modified (see the Systems Descriptions section). No arresting gear malfunctions were experienced. The BAK-13 performed satisfactorily for all tests, and its energy absorbing capacity was well in excess of the kinetic energy generated by the A-7D (figure 26).

Hookloads and brake tape tensions were compared to data obtained in reference 6. Hookloads (figure 13) agreed favorably within limits of normal scatter expected with this data. A discussion of aircraft hookloads can be found in the A-7D Evaluation section of this report. Maximum average tape tensions for the BAK-13 are shown in figure 32 for centerline, 35-, and 50-foot off-center engagements. Typical characteristic traces of hookloads and tape tensions versus time are shown in figures 30 and 31. Maximum tape tensions occurred at the beginning of the braking region (figure 31). All tape loads were well within design limits of the BAK-13.

Data on tape and hook impact loads, tub and return line pressures, tub and return line temperatures, aircraft runout, etc., can be found in appendix I.

Extended Runout BAK-12

The extended runout BAK-12 Aircraft Arresting Barrier System is a growth version of the standard BAK-12. Although it was not tested in this program, the A-7D and the extended runout BAK-12 are considered compatible based on these and other tests. A performance comparison of the BAK-12 systems is shown in table III.

Testing of the extended runout BAK-12 was done with the F-111A at 60,000 to 90,000 pounds (reference 7). No tests at lighter aircraft weights have been made but the system is in common use within the Air Force. Its characteristics are similar to those of the standard BAK-12

except that peak hookloads and tape tensions may actually be lower since the load peak will not occur at the end of the runout.

Cable Support Evaluation

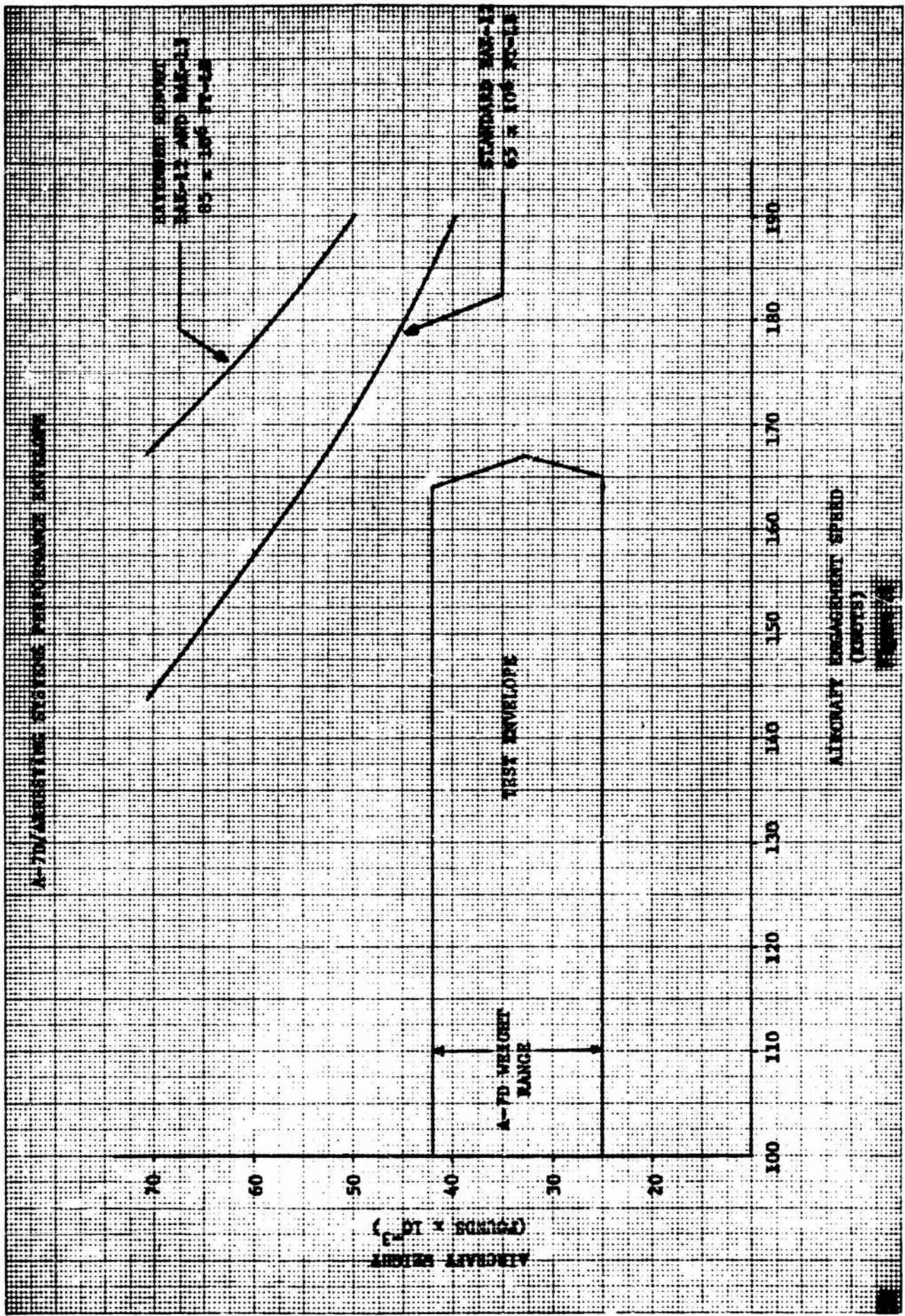
Three types of cable supports were evaluated: polyurethane rails, standard donuts, and heavy duty (Navy) donuts (figures 9, 10, and 11). Each cable support was tested with the A-7D for a particular reason. Polyurethane rails were evaluated for use with the BAK-13 and were necessary for rapid cycle arrestments. Standard donuts were the accepted Air Force cable support at this time. Heavy duty donuts may replace the Air Force donuts as the standard cable support.

Analysis of test film showed that each cable support caused the arresting cable to react considerably different during an arrestment. Ideally, the arresting cable recovered from landing gear rollover by quickly rising above the runway surface. If the nose of the hook shoe was higher than the centerline of the cable at the instant of hook impact, the hook skipped over the cable.

Polyurethane rails produced slow cable recovery times when the aircraft main gear passed between any two rails, thus causing the arresting cable to lay on or near the runway surface at hook impact. This condition contributed to three missed engagements (tests 7, 18, and 74). Further testing with the aircraft straddling a rail support showed that the cable recovered more quickly and to a height above the runway of approximately five inches. In this mode, there were no additional missed engagements. A rail was struck by a main tire on at least 1 test (test No. 73) at 32,400 pounds gross weight and 155 knots. There was no apparent damage to the tire.

The donut cable supports showed arresting cable recovery times shorter than those of polyurethane rails. The heavy duty donuts produced arresting cable peak heights slightly greater than those of the standard donuts, about seven inches. The donuts themselves helped to drive the arresting cable away from the runway surface after landing gear rollover. One missed engagement occurred with standard donuts.

Test results indicated that standard and heavy duty donuts were acceptable cable supports. Conversely, polyurethane rails produced unacceptable cable dynamics when the main gear passed between two rails, thus resulting in insufficient arresting cable heights above the runway surface. The poor characteristics of cable recovery when the polyurethane rail supports were used was a major factor in causing missed engagements. Figure 33 shows typical cable recovery with heavy duty donuts, standard donuts, and polyurethane rails. Further testing of polyurethane rails is necessary to determine their optimum spacing for use with the A-7D.
(R 6)



A-7E HOOK EVALUATION TESTS
MAXIMUM AVERAGE TAPE TENSION PERFORMANCE

— TAPE OPERATION LIMIT —
63,000 POUNDS

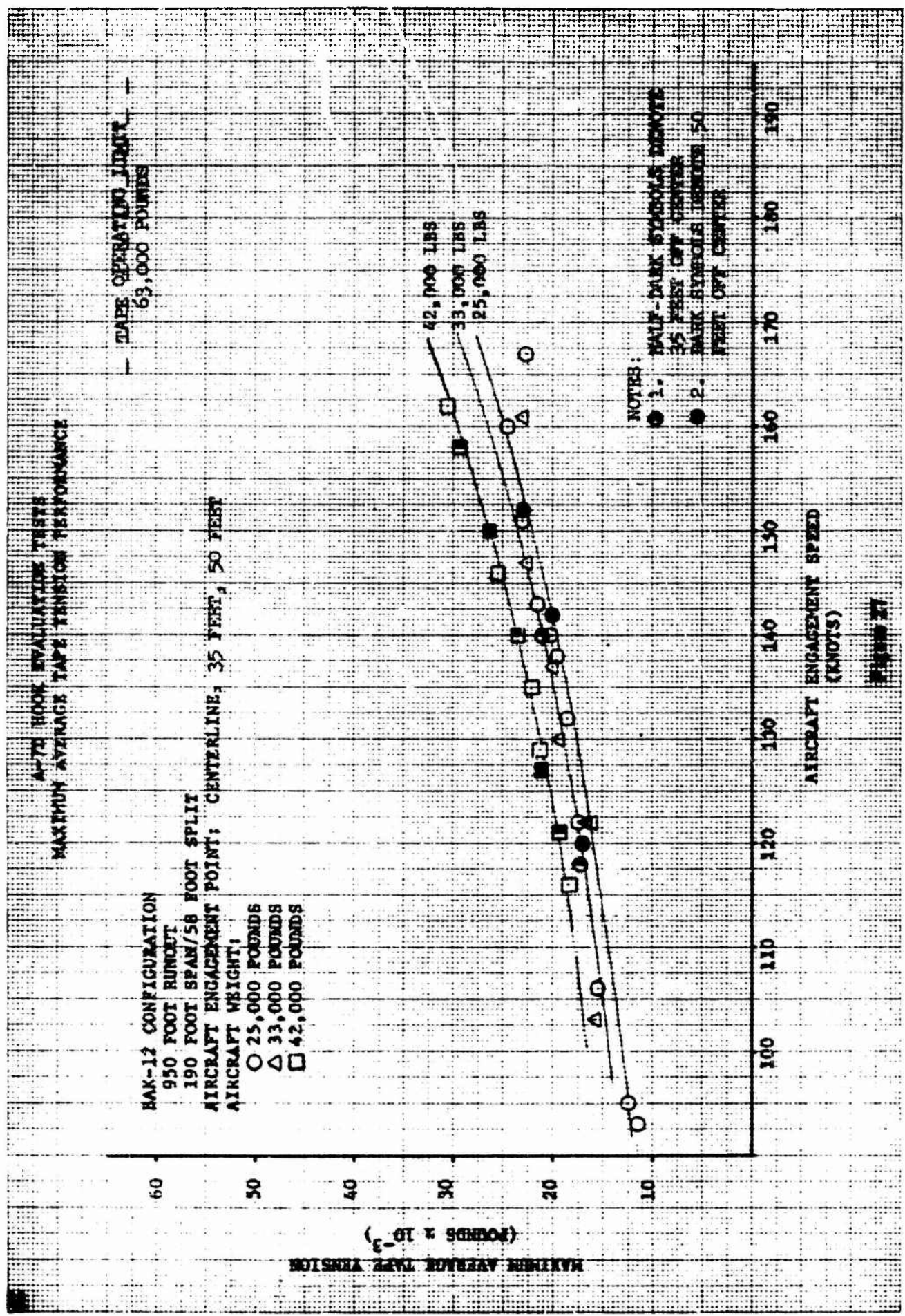
BAK-12 CONFIGURATION
950 FOOT RUNOUT
190 FOOT SPAN/58 FOOT SPLIT
AIRCRAFT ENGAGEMENT POINT: CENTERLINE, 35 FEET, 50 FEET
AIRCRAFT WEIGHT:
○ 25,000 POUNDS
△ 33,000 POUNDS
□ 42,000 POUNDS

MAXIMUM AVERAGE TAPE TENSION
(POUNDS $\times 10^{-3}$)

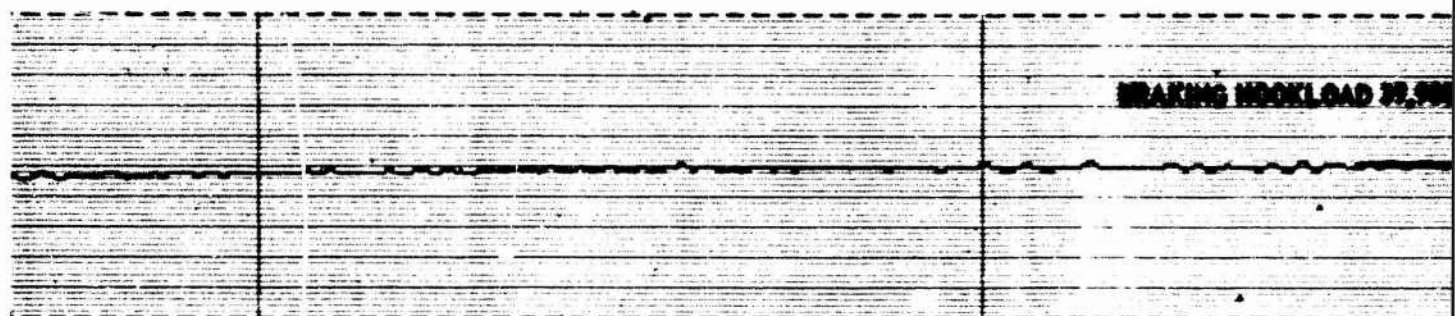
NOTES:
1. HALF-DARK SYMBOLS DENOTE
35 FEET OFF CENTER
2. DARK SYMBOLS DENOTE 50
FEET OFF CENTER

AIRCRAFT ENGAGEMENT SPEED
(KNOTS)

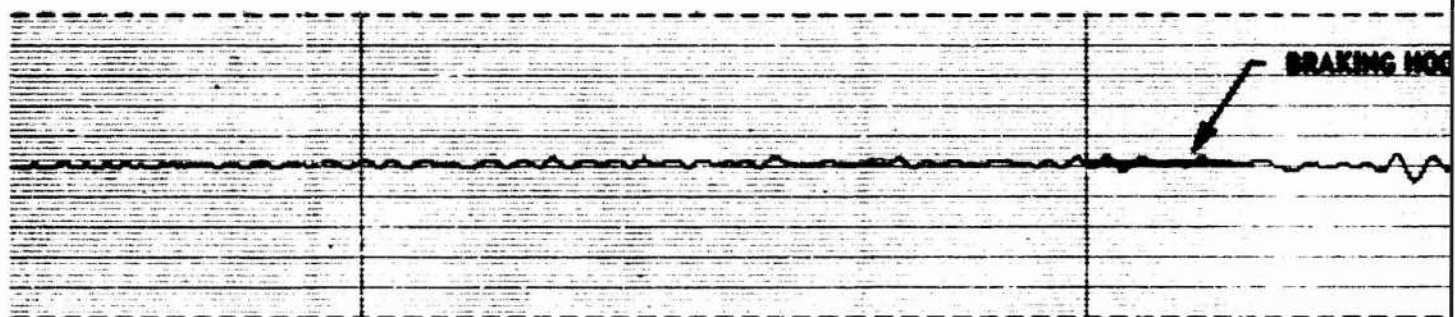
FIGURE 27



Test 35; 25,440 Pounds/



Test 44; 33,075 Pounds/



Test 53; 40,255 Pounds/

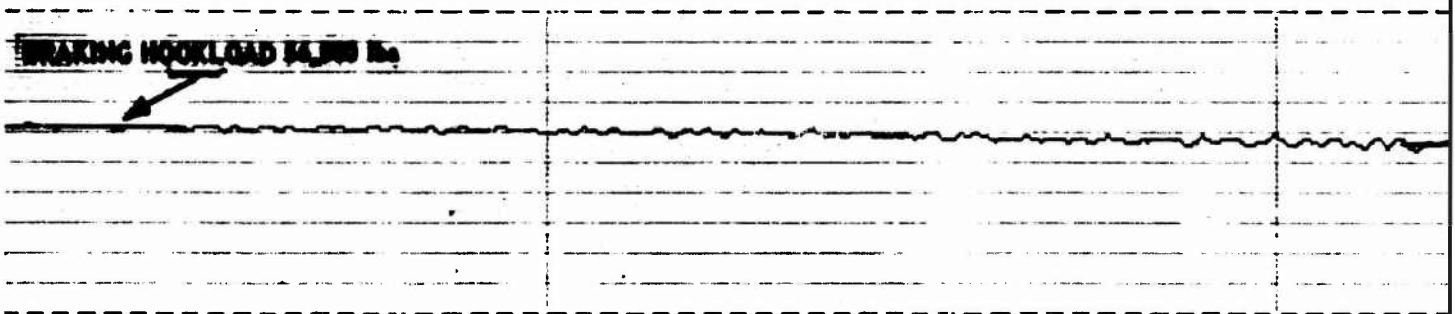
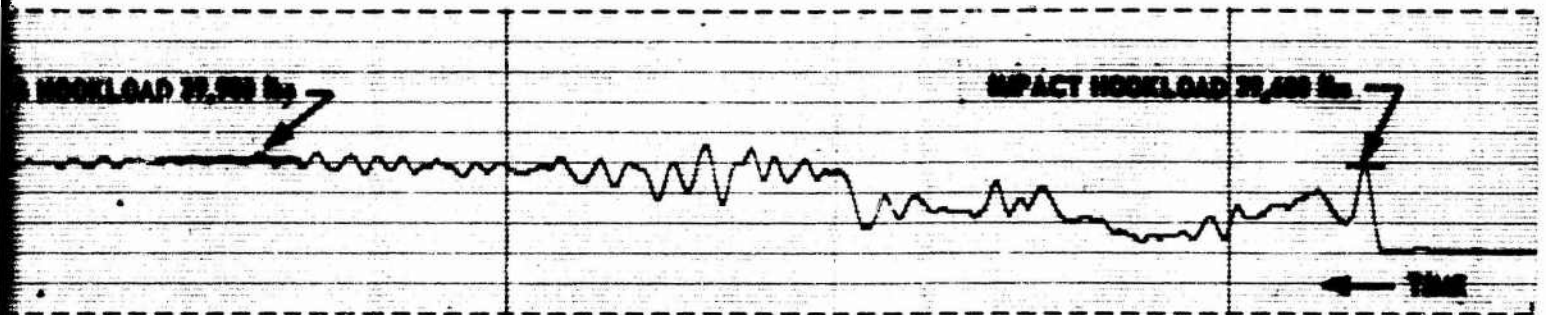
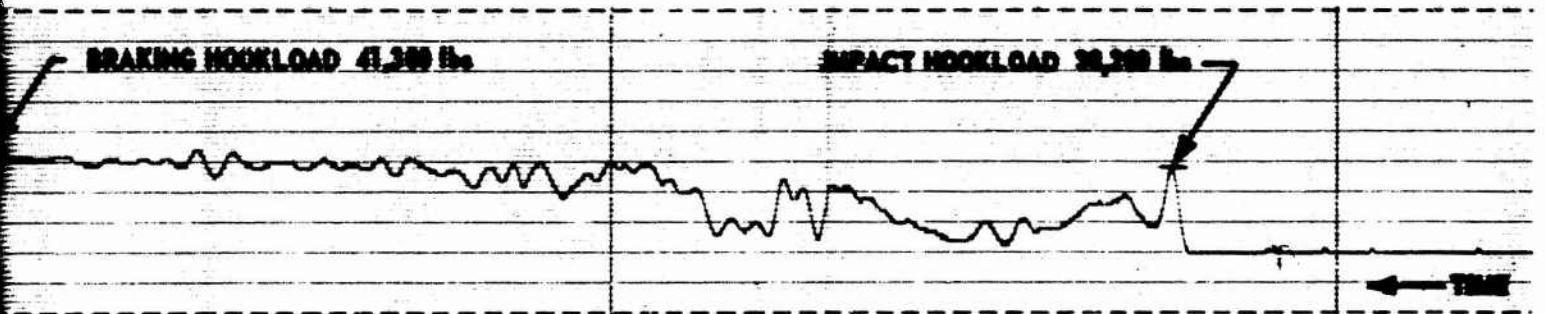


Figure 28 BAK-12 Typical H

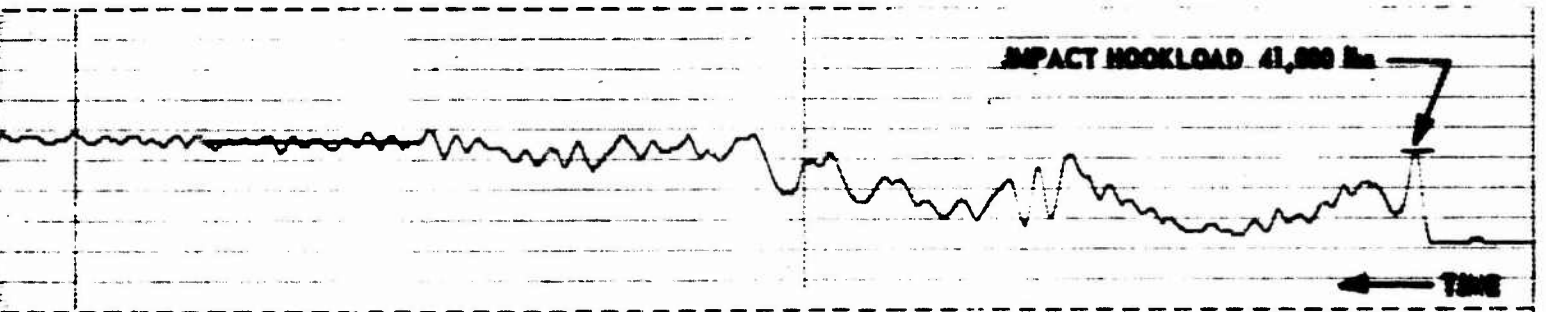
25,440 Pounds/130 Knots



33,075 Pounds/147 Knots



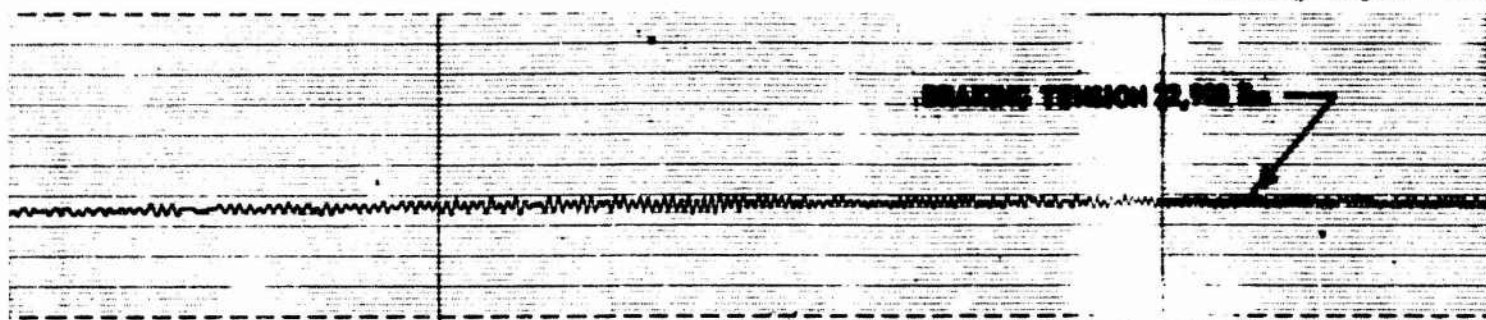
40,255 Pounds/149 Knots



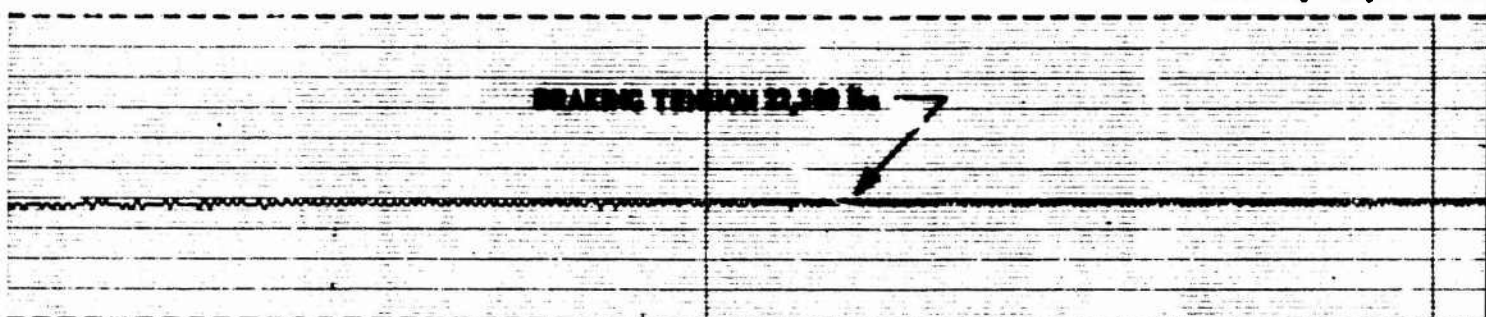
BAK-12 Typical Hookload Time Histories

2

Test 33; 25,400 Pounds



Test 44; 33,075 Pounds



Test 53; 40,255 Pounds

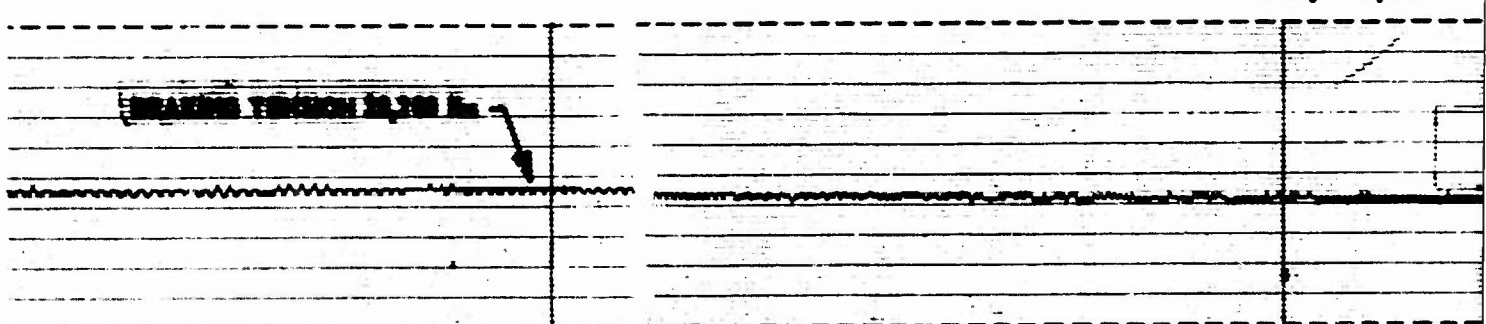
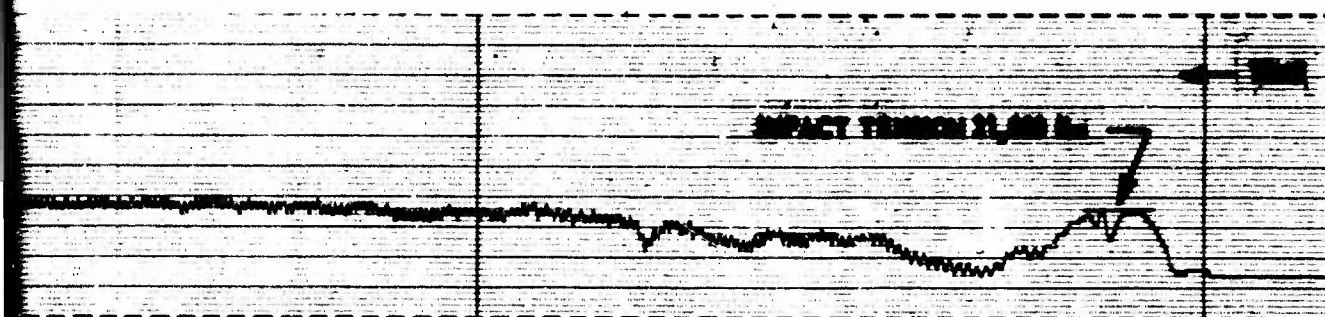
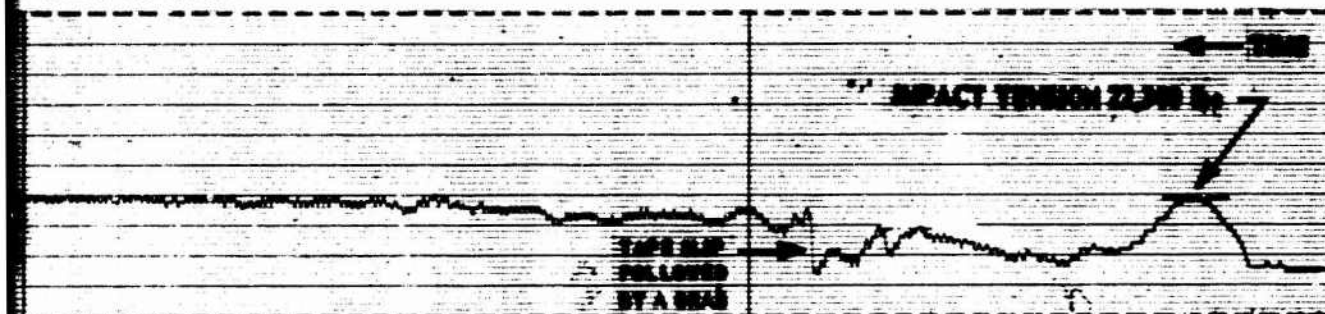


Figure 29 BAK-12 Typical Tape Test

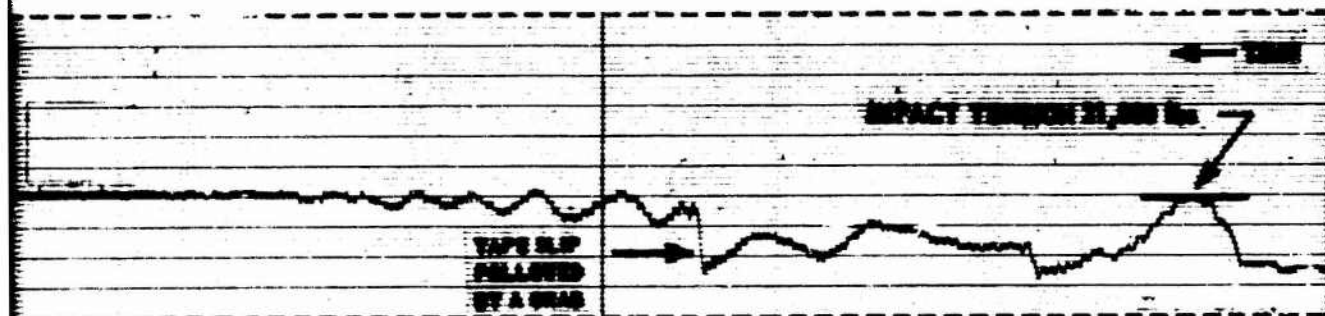
Pounds/150 Knots



Pounds/140 Knots



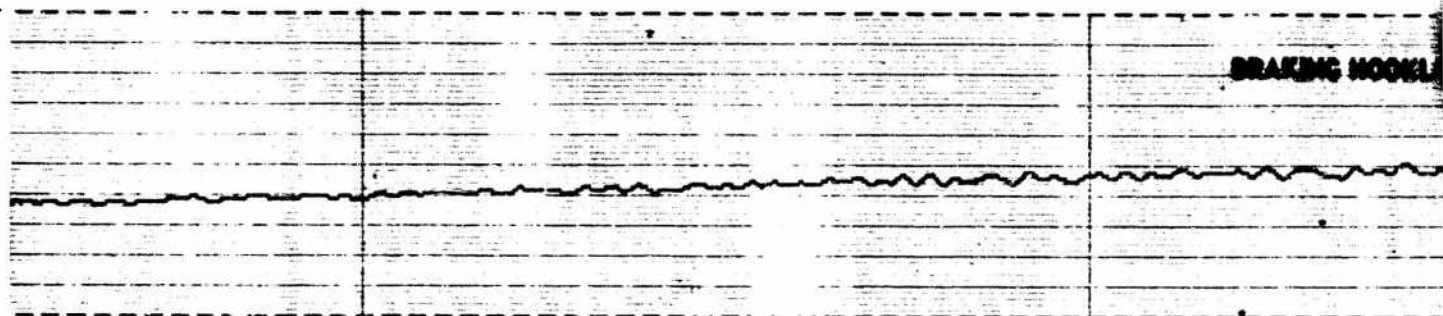
Pounds/149 Knots



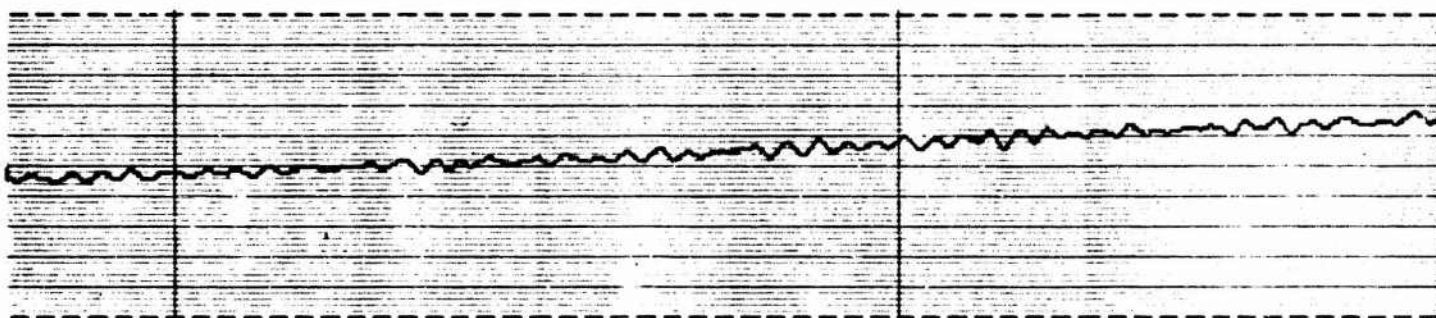
Tension Time Histories

2

Test 04: 26,449 Pounds



Test 22: 33,900 Pounds



Test 65: 41,105 Pounds

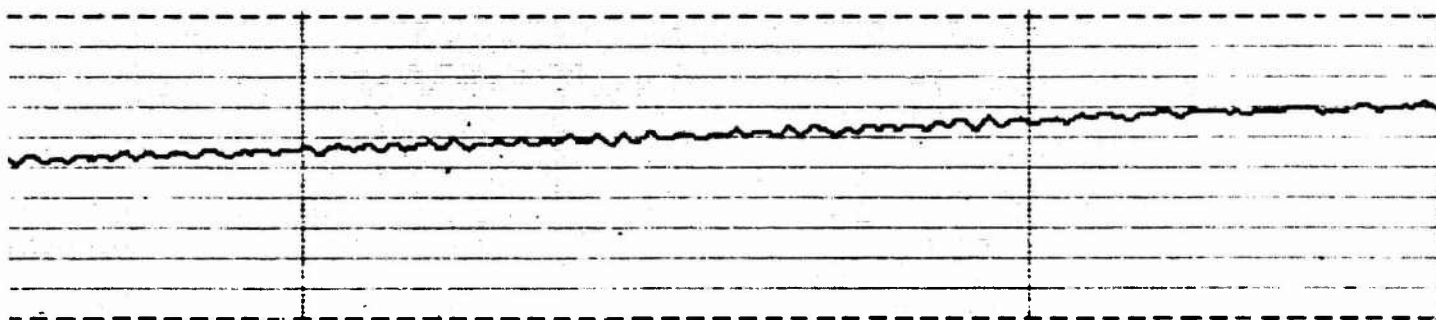
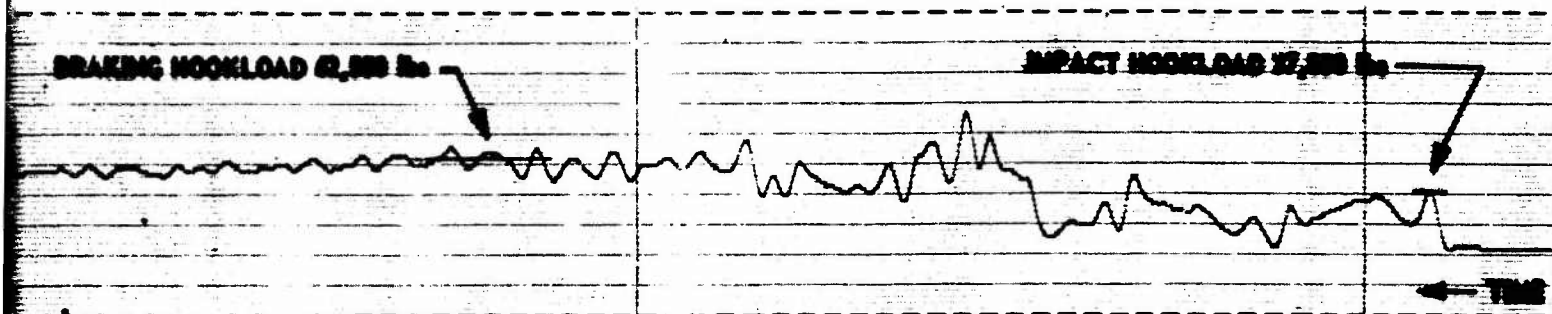
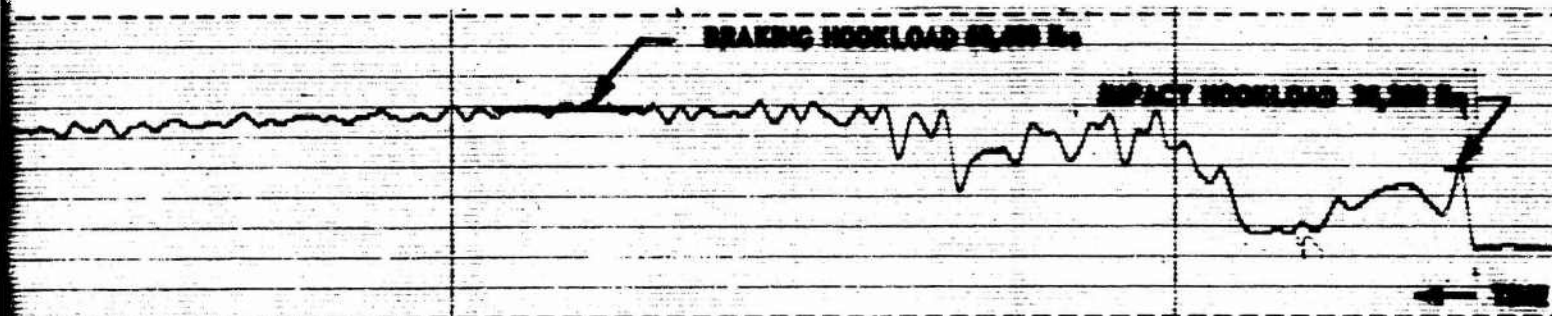


Figure 30 BAK-13 Typ

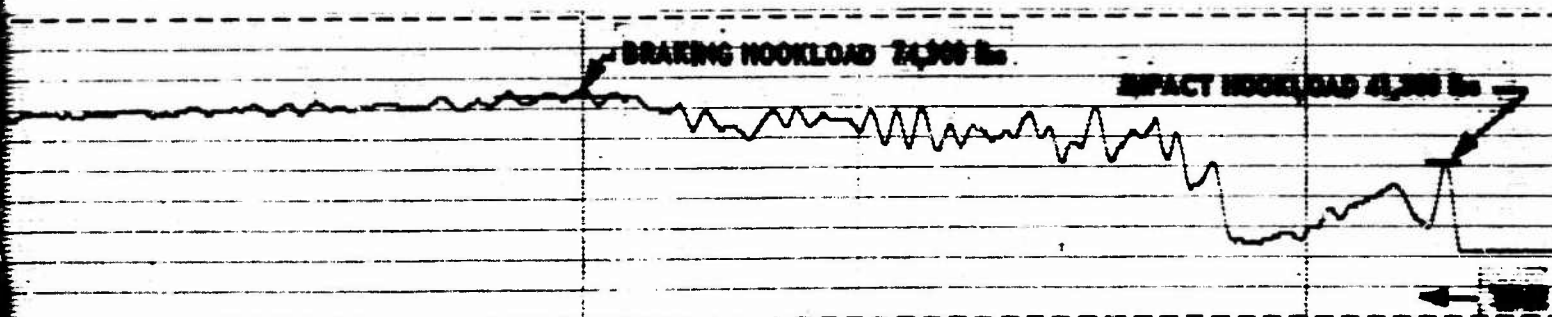
Jet 84: 26,440 Pounds/149 Knots



Jet 22: 33,900 Pounds/148 Knots



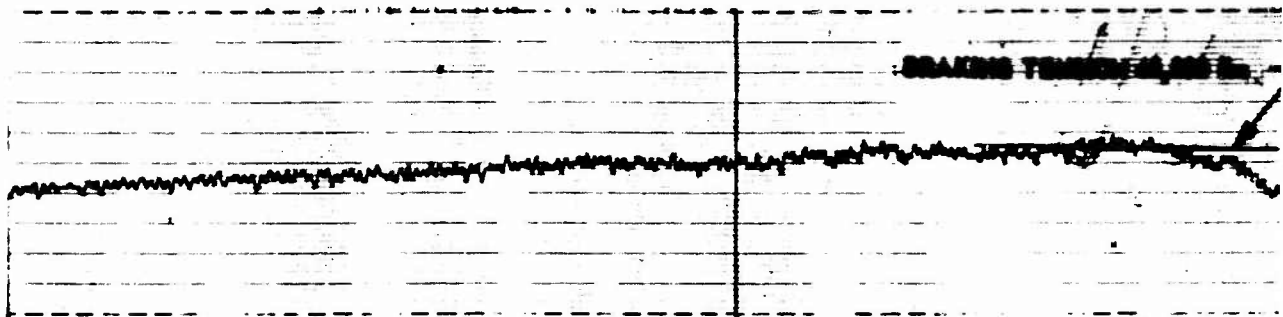
Jet 65: 41,135 Pounds/152 Knots



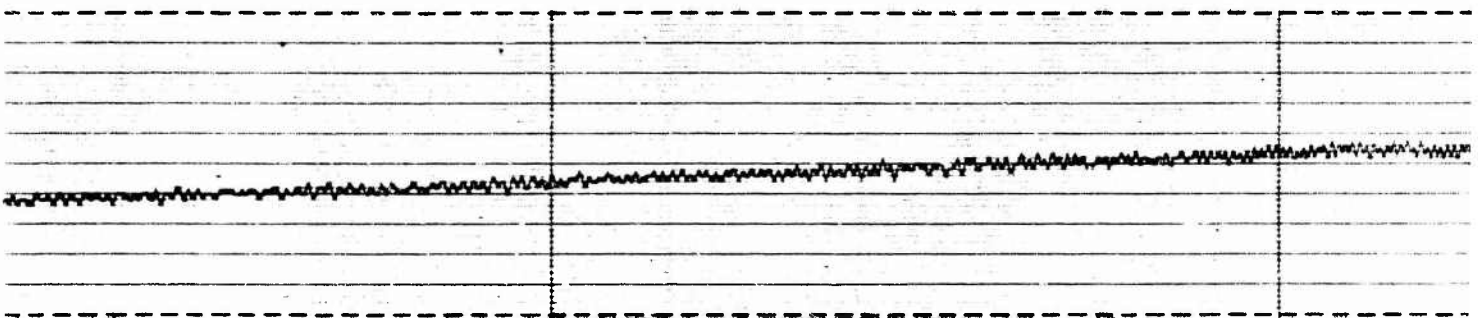
Page 30 BAK-13 Typical Hookload Time Histories

2

Test 04: 26,440 Pounds/140 Kpa



Test 22: 33,900 Pounds/148 Kpa



Test 65: 41,105 Pounds/152 Kpa

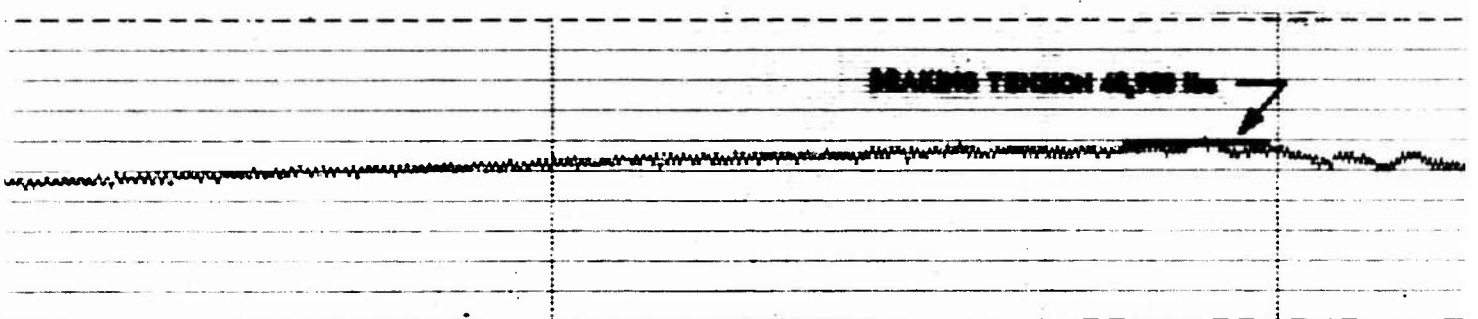
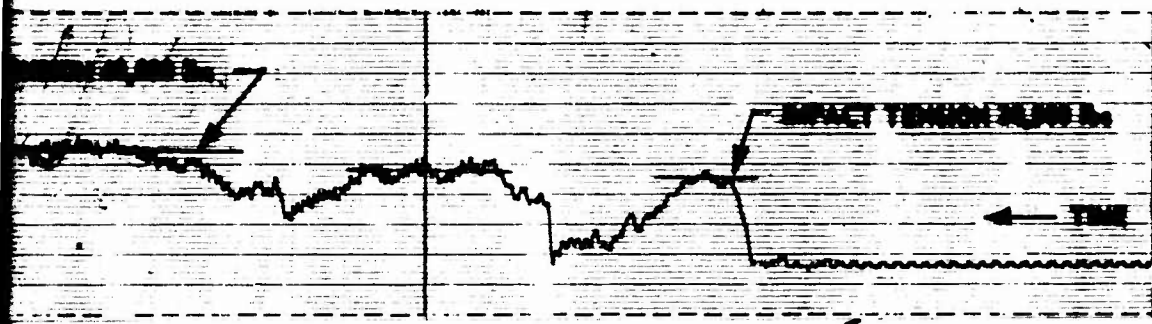
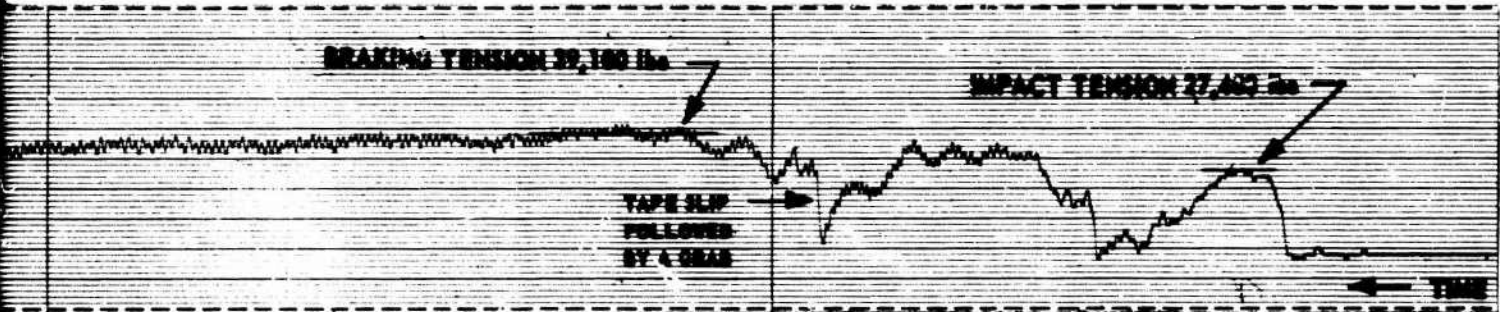


Figure 21 BAK-12 Typical Tape Tensi

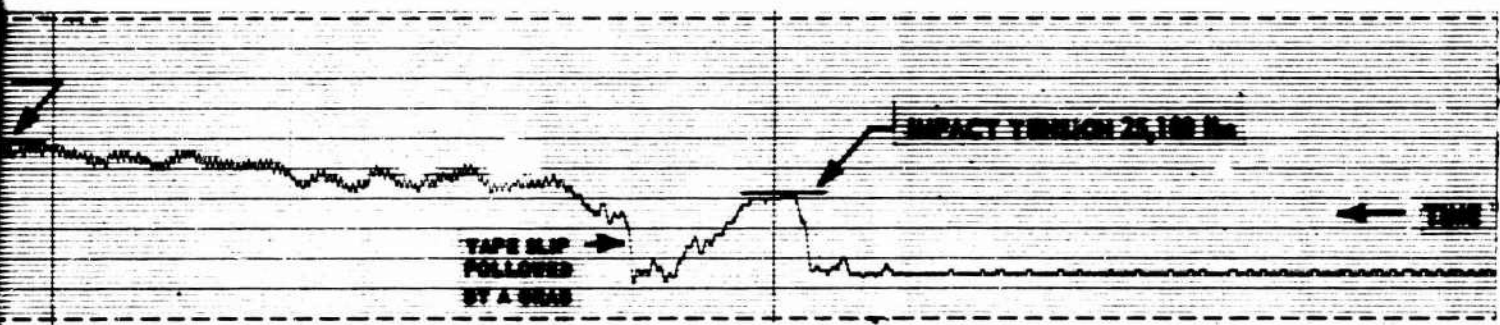
10 Pounds/140 Knots



900 Pounds/148 Knots



41,105 Pounds/152 Knots



Typical Tape Tension Time Histories

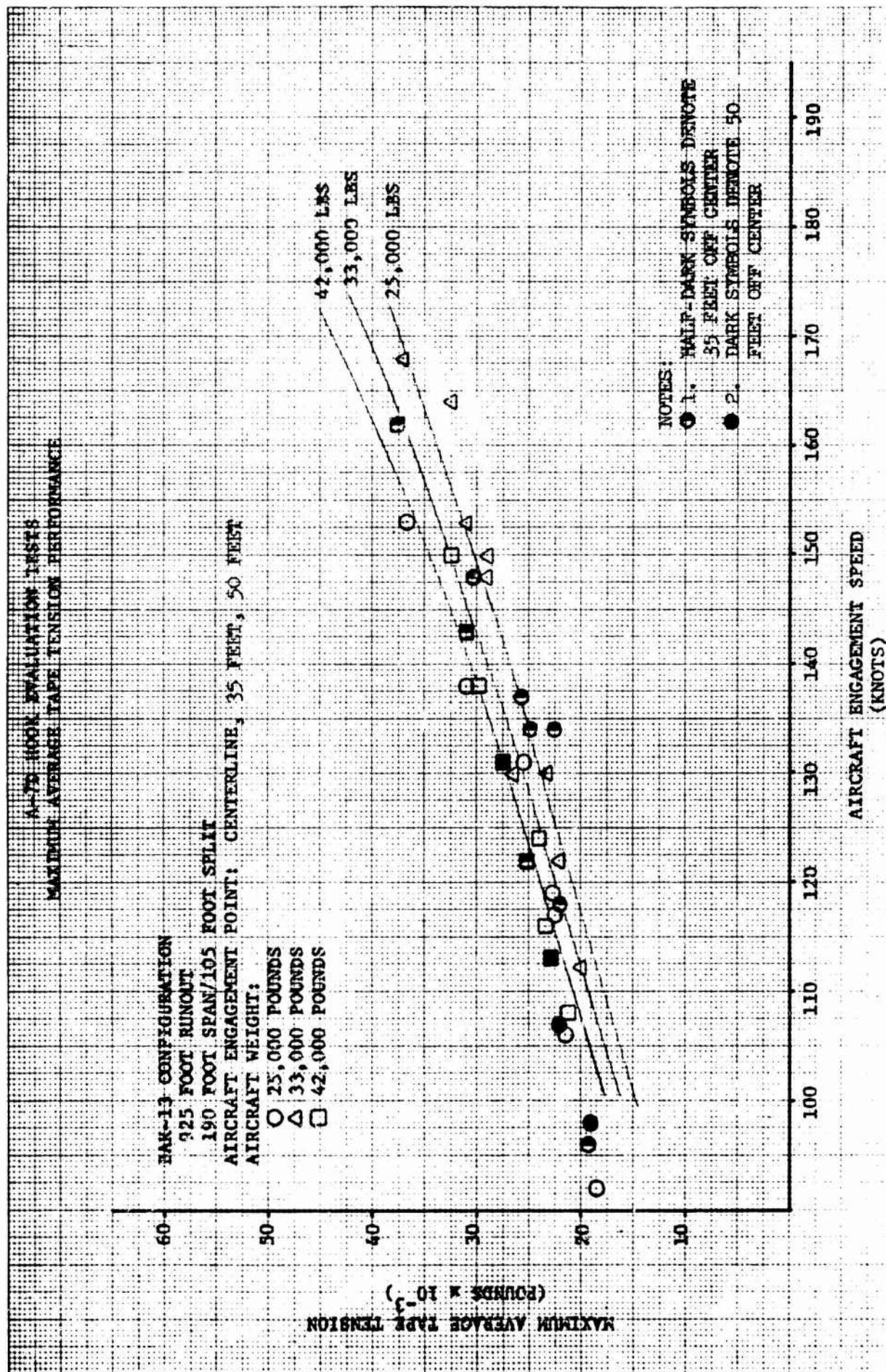


Figure 32

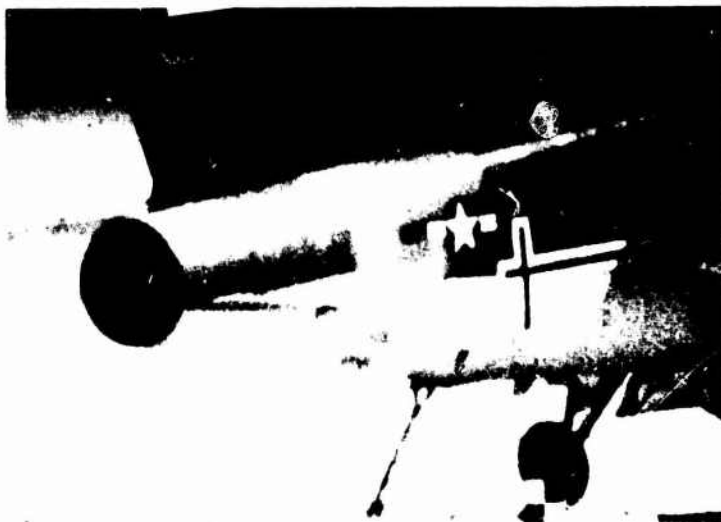
NOT REPRODUCIBLE

Table III

STANDARD AND EXTENDED RUNOUT
BAK-12 ARRESTING SYSTEMS COMPARISON

	BAK-12 Arresting Systems	
	Standard 950-ft Runout	Extended 1,200-ft Runout
Cam Gearbox Sprocket (T.O. 35E8-2-5-4, Figure 17, Index B7)	52-W-2299-7 (28 teeth)	52-W-2299-33 (32 teeth)
Synchronizing Pressure	800 psi	1,100 psi
Normal Tape Stack Diameter	60 in.	66 in.
Design Aircraft Weight Setting	40,000 lb	50,000 lb
Energy Absorbing Capacity	65×10^6 ft-lb	98.5×10^6 ft-lb

NOT REPRODUCIBLE



POLYURETHANE RAILS

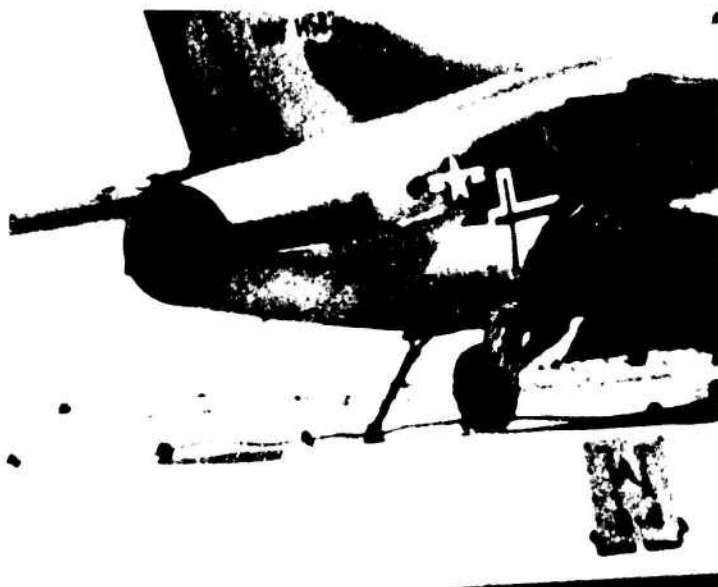
Figure 33 Typical Cable Dynamics for Polyurethane Rails, Heavy Duty (Navy) Donuts, and Standard (Air Force) Donuts



HEAVY DUTY (NAVY) DONUTS



NOT REPRODUCIBLE



STANDARD (AIR FORCE) DONUTS

Figure 3% (Concluded)

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of these tests, the A-7D was shown to be compatible with the standard BAK-12 and BAK-13 aircraft arresting systems using donut type cable supports (but not with rail type cable supports as discussed later), and was tested to engagement speeds of 167 knots at gross weights through 42,000 pounds. Extrapolation of the data showed that the A-7D design limit hook load would only be approached at an engagement speed well in excess of 190 knots at 42,000 pounds for either arresting system. Approach end engagements presented no particular problems. The pilot could detect a noticeable difference in the onset of braking loads between the standard BAK-12 and the BAK-13 arresting systems.

The A-7D Flight Manual procedures for approach end engagements were generally satisfactory but further explanation and minor procedures changes were considered necessary.

1. The changes listed on pages 15 and 16 of this report are recommended for the Approach End Engagement section of the Flight Manual (pages 12 and 14).

For centerline engagements, decelerations were smooth and lateral displacement was slight with either arresting system. The off-center engagements resulted in roll and yaw oscillations, which were generally more severe at the 50-foot off-center condition. The yaw could be controlled by the pilot without difficulty.

The Flight Manual does not warn the pilot that nosewheel steering will be inoperative during arresting gear engagements if the engine is shut down. Hook extension time was considered to take longer than is desirable for an emergency arrestment. A one second time would be more desirable. No engagements were missed during the test program as a result of hook extension time. The Flight Manual calls for extending the hook at least 2,000 feet prior to the arresting gear which is greater than the minimum distance necessary. Either arresting system is capable of arresting the A-7D at maximum gross weight without jettisoning external stores. Maximum test speed was 167 knots which is well above normal takeoff and landing speeds. Extrapolation of test data indicated that aircraft hook loads and arresting system energy limits would not be exceeded up to the theoretical 190-knot arresting system limit. The aircraft tire limit of 174 knots must be considered. Blown tires will reduce chances of a successful engagement. Aircraft rollback should be anticipated by the pilot for high energy engagements of the BAK-12 arresting system.

2. The Abort/Barrier Engagement section of the A-7D Flight Manual should include the changes listed on page 16 of this report (pages 13 and 14).

Aircraft arresting gear operational disengagement procedures were developed as a result of testing. These procedures should be followed to insure rapid aircraft disconnect from the arresting gear.

3. The changes listed on page 16 of this report are recommended for inclusion in the A-7D Flight Manual (page 15).

The hook actuator snubbing load limit was exceeded on several tests and particularly on engagements of the BAK-13. The actuator rod end load limit should be increased. A DR is in process.

The A-7D exhibited poor engagement reliability primarily due to a poor attitude of the hook shoe which allowed the shoe nose centerline to be well above the runway surface even when the hook was resting on the runway and the use of rail type cable supports at the standard 14- and 18-foot spacing (see R 6). Hook skip was judged to be light to moderate and was not a significant factor in the four missed engagements experienced in these tests. The hook shoe attitude problem was considered a significant safety hazard, and DR No. F406-184 was submitted recommending that the hook shoe be redesigned so that the hook shoe nose stays on the runway surface, regardless of hook shank angle.

4. Further testing of any redesigned hook shoe should be accomplished (page 27).

The aircraft hook shoe wear resulted in frequent shoe replacements. If the shoe is left on the runway for a long distance prior to an engagement, the wear can result in a failure. The A-7D hook shoe must be redesigned to reduce wear. A DR is in process.

The improved hook bumper was superior to the original bumper, but it also failed and was lost on the last test.

5. Further investigation should be made to determine suitability of the improved hook bumper for operational use (page 36).

The aircraft tires were very susceptible to damage due to cable rollover and frequent tire changes will be required in an operational environment. The A-7D tires should be improved to reduce their susceptibility to damage due to cable rollover at high speeds. DR No. F408-185 has been submitted.

The heavy duty (Navy) donut cable supports appeared to provide the most satisfactory cable response following landing gear rollover based on a limited number of tests. One missed engagement resulted, while using the standard Air Force donuts, but was due partly to a nose-high attitude of the hook shoe. The donut supports were considered acceptable. Three engagements were missed while using the polyurethane cable supports due to poor response of the cable following the landing gear rollover when both main gear tires passed between two rails.

6. Further testing of polyurethane rails is necessary to determine their optimum spacing for use with the A-7D (page 40).

APPENDIX I

Test Data

FLIGHT

AF NO FLIGHT NO TEST
ENGINE NO FUEL CONFIGURATION

DATE	PROGRAM NUMBER	AIRCRAFT TYPE	AIRCRAFT WEIGHT (LB x 10 ⁻³)	AIRCRAFT SPEED (Knots)	KINETIC ENERGY (FT-LB x 10 ⁻⁶)	ENGAGEMENT DISTANCE FPOB CENTERLINE (FEET)	AIRCRAFT RUNOUT (FEET)	LATERAL DISPLACEMENT (FEET)	IMPACT HOOKLOAD (LB x 10 ⁻³)	BRAKE HOOKLOAD (LB x 10 ⁻³)	MAXIMUM DASHPOT LOAD (LB x 10 ⁻³)	MAX HOOK SIDELOAD (LB x 10 ⁻³)	MAX AVG TAPE TENSION (LB x 10 ⁻³)	MAX AVG LT & RT TAPE TENSION (LB x 10 ⁻³)
23 Mar	1	A-7D	26.6	54	3.4	0	750	35R	53.9	10.2	-	6.9	8.0	8.7
												20.8		7.3
23 Mar	2	A-7D	25.8	40	9.3	0	825	2L	20.3	26.0	-	3.6	18.7	18.6
												8.3		18.7
23 Mar	3	A-7D	25.2	105	12.4	0	840	0	21.1	29.5	17.1	6.8	21.5	25.9
												5.4		17.1
25 Mar	4	A-7D	26.4	149	26.1	0	805	3L	37.9	62.6	16.5	4.2	36.6	35.3
												9.2		37.9
25 Mar	5	A-7D	25.9	137	21.6	0	700	4R	34.0	53.8	16.9	14.1	30.8	27.7
												10.7		33.8
25 Mar	6	A-7D	25.4	118	15.7	0	780	8L	25.5	37.9	16.5	2.4	22.7	23.2
												4.8		22.1
26 Mar	7	A-7D	27.1	131	21.3	0	-	-	-	-	-	-	-	-
30 Mar	8	A-7D	27.2	112	15.1	0	807	0	13.9	33.2	16.0	4.2	22.5	21.0
												5.9		23.9
30 Mar	9	A-7D	26.6	127	19.1	0	820	0	28.6	46.6	16.0	6.5	25.6	26.6
												5.3		24.6
2 Apr	10	A-7D	27.0	129	19.9	35L	809	12L	25.5	49.6	15.7	4.8	24.7	27.9
												13.7		21.4
2 Apr	11	A-7D	26.3	127	19.8	35L	805	12L	25.4	44.7	-	3.9	22.4	27.9
												12.6		16.8
2 Apr	12	A-7D	25.4	136	20.8	35L	815	14L	27.7	50.4	15.7	6.5	25.6	29.8
												17.2		21.4
2 Apr	13	A-7D	25.2	147	24.1	35L	825	12L	35.2	57.5	17.7	5.4	30.3	32.1
												21.4		28.4
5 Apr	14	A-7D	25.8	95	10.3	35L	765	12L	14.6	27.8	16.9	6.1	19.3	19.6
												3.1		19.0
5 Apr	15	A-7D	25.5	117	15.5	35L	790	12L	22.8	41.3	17.2	4.9	22.2	24.4
												12.9		20.1
5 Apr	16	A-7D	25.3	97	10.6	50R	760	37R	18.5	29.5	16.2	6.1	19.0	17.4
												5.5		20.5
5 Apr	17	A-7D	25.0	107	12.7	50R	775	25R	19.9	36.9	16.1	10.0	21.9	21.4
												6.0		22.4
5 Apr	18	A-7D	24.7	117	15.0	50R	-	-	-	-	-	-	-	-
12 Apr	19	A-7D	34.2	110	17.6	0	840	3R	24.1	37.5	17.6	4.9	19.9	20.5
												7.3		19.2
12 Apr	20	A-7D	34.0	120	21.3	0	800	2R	27.1	41.3	17.9	8.9	22.1	22.9
												7.7		21.3
12 Apr	21	A-7D	33.8	129	25.0	0	855	5R	29.9	50.4	16.8	4.9	26.3	28.8
												10.1		23.8
16 Apr	22	A-7D	33.9	148	33.0	0	863	11L	35.2	60.4	17.3	7.1	29.3	33.3
												15.5		25.2

PRECEDING PAGE BLANK NOT FILMED.

FLIGHT DATA SHEET

TEST

DATE

DURATION

	(LB x 10 ⁻³)	MAX AVG TAPE TENSION (LB x 10 ⁻³)	MAX AVG LT & RT TAPE TENSION (LB x 10 ⁻³)	SIDE OF RUNWAY	IMPACT TAPE TENSION (LB x 10 ⁻³)	BRAKE TAPE TENSION (LB x 10 ⁻³)	MAXIMUM AVG CHANGE TUR TEMP (°F)	MAXIMUM AVG CHANGE TUR PRESS (PSI)	MAXIMUM AVG CHANGE TUBE TEMP (°F)	MAXIMUM AVG CHANGE TUBE PRESS (PSI)	PENDANT NUMBER	TAPE NUMBER	TAPE CONNECTOR	SUPPORTS* AND SPACING (FEET)	ARRESTING SYSTEM	COMMENTS			
2.9	8.0	8.7	L	11.4	6.0	17.7	14.9				1	1	1	R	BAKIS				
0.8		7.3	R	10.9	3.6									14/18					
2.6	18.7	18.6	L	23.0	14.1	15.9	32.2												
3.3		18.7	R	18.4	19.0														
2.8	21.5	25.9	L	25.4	25.9	19.4	40.8												
2.4		17.1	R	17.7	16.4														
1.8	36.6	35.3	L	30.5	40.0	21.2	42.7												
2.2		37.9	R	29.0	46.9														
4.1	30.8	27.7	L	24.8	30.5	19.4	75.6												
0.7		33.8	R	27.6	40.0														
2.4	22.7	23.2	L	24.2	22.2	16.3	56.3												
2.8		22.1	R	22.8	21.4														
-	-	-	L	-	-	-	-												
-	-	-	R	-	-	-	-												
2.2	22.5	21.0	L	22.9	19.1	12.4	50.8												
1.9		23.9	R	27.8	20.0														
2.5	25.6	26.6	L	25.2	27.9	22.5	62.3												
2.3		24.6	R	23.0	26.2														
4.8	24.7	27.9	L	26.0	29.8	17.6	59.5				2								
3.7		21.4	R	21.4	21.4														
5.9	22.4	27.9	L	26.0	24.8	14.1	61.5												
2.6		16.8	R	19.1	14.5														
2.5	25.6	29.8	L	27.9	31.6	17.6	65.7												
2.2		21.4	R	21.8	20.9														
2.4	30.3	32.1	L	28.8	35.3	20.9	70.3												
2.1		28.4	R	27.3	29.4														
6.1	19.3	19.6	L	19.1	20.0	12.4	35.8												
3.1		19.0	R	20.0	18.0														
4.9	22.2	24.4	L	23.4	25.4	16.1	54.5												
2.9		20.1	R	22.9	17.2														
6.1	19.0	17.4	L	21.5	13.2	9.1	37.5												
5.5		20.5	R	21.4	19.5														
0.0	21.9	21.4	L	21.9	20.9	17.9	43.5												
6.0		22.4	R	22.4	21.9														
-	-	-	L	-	-	-	-												
-	-	-	R	-	-	-	-												
1.4	19.9	20.5	L	20.5	20.5	15.7	44.1	8.4											
7.3		19.2	R	18.7	14.6														
8.9	22.1	22.9	L	21.0	24.8	17.6	57.7	11.6											
7.7		21.3	R	20.4	22.2														
4.9	26.3	28.8	L	25.4	32.2	21.2	62.3	10.7											
0.1		23.8	R	21.7	25.8														
7.1	29.3	33.3	L	27.4	39.1	27.9	82.9	15.3	86.9					S					
5.5		25.2	R	21.2	29.4									S					

*R - Rails HD - Heavy Duty Donuts
S - Standard Donuts

2

FLIGHT DATA SHEET

AF NO FLIGHT NO TEST
ENGINE NO FUEL CONFIGURATION

DATE	PROGRAM NUMBER	AIRCRAFT TYPE	AIRCRAFT WEIGHT (LB x 10 ⁻³)	AIRCRAFT SPEED (knots)	KINETIC ENERGY (FT - LB x 10 ⁻⁶)	ENGAGEMENT DISTANCE FROM CENTERLINE (FEET)	AIRCRAFT RUNOUT (FEET)	LATERAL DISPLACEMENT (FEET)	IMPACT HOOKLOAD (LB x 10 ⁻³)	BRAKE HOOKLOAD (LB x 10 ⁻³)	"MAXIMUM" DASHPOT LOAD (LB x 10 ⁻³)	MAX HOOK SIDELOAD (LB x 10 ⁻³)	MAX AV3 TAPE TENSION (LB x 10 ⁻³)	MAX AVG LT & RT TAPE TENSION (LB x 10 ⁻³)	SIDE OF RAMPWAY	IMPACT TAPE TENSION (LB x 10 ⁻³)	BRAKE TAPE TENSION (LB x 10 ⁻³)
16 Apr	23	A-7D	33.7	121	21.8	0	790	12L	27.5	44.0	16.9	4.3	22.2	23.9	L	22.4	25.4
16 Apr	24	A-7D	33.4	147	31.9	0	815	10L	42.0	65.6	17.3	6.1	29.4	20.4	R	19.2	21.6
16 Apr	25	A-7D	33.1	130	24.8	0	805	8L	33.9	48.1	18.1	6.5	23.2	26.4	R	22.4	30.4
16 Apr	26	A-7D	32.7	165	39.5	0	885	3L	46.8	74.3	-	7.3	32.7	26.7	L	24.8	28.6
												7.3	32.7	22.4	R	21.6	23.2
												10.7	32.7	36.2	L	24.5	42.8
													29.2	29.2	R	23.7	36.0
TESTS NO. 27 - 60 with the STAN																	
7 Jun	61	A-7D	41.9	116	25.0	0	900	20L	26.9	46.7	18.9	6.5	23.4	23.8	L	21.4	26.1
7 Jun	62	A-7D	41.5	139	35.5	0	920	6L	34.0	62.2	18.9	7.1	29.8	23.0	R	21.4	24.6
7 Jun	63	A-7D	41.1	125	28.5	0	905	3L	31.2	51.0	19.9	7.1	24.0	29.0	L	22.7	35.3
8 Jun	64	A-7D	41.5	109	21.8	0	905	2L	23.4	39.9	18.7	8.6	21.2	30.5	R	24.8	36.2
8 Jun	65	A-7D	41.1	152	42.0	0	920	0	41.3	74.3	21.3	8.3	21.2	23.8	L	20.5	27.0
8 Jun	66	A-7D	40.8	160	46.3	0	925	0	48.1	80.6	18.3	11.3	32.5	24.2	R	21.4	27.0
9 Jun	67	A-7D	41.5	123	27.7	35L	895	20L	25.4	48.2	18.1	11.9	25.2	21.0	L	20.5	21.4
9 Jun	68	A-7D	41.2	144	37.8	35R	885	2R	31.1	62.3	19.4	14.9	31.0	31.9	R	24.6	39.1
9 Jun	69	A-7D	40.7	164	48.5	35L	925	0	41.0	82.1	20.0	9.3	37.7	28.6	L	27.3	41.8
10 Jun	70	A-7D	41.4	114	23.7	50L	880	0	19.8	42.5	18.0	26.8	22.8	27.0	L	24.2	29.6
10 Jun	71	A-7D	41.1	133	32.2	50R	900	0	24.0	55.1	18.8	12.9	22.5	23.3	R	21.4	25.1
11 Jun	72	A-7D	33.4	167	41.2	0	875	8L	46.7	83.4	22.6	8.3	37.0	29.3	L	26.0	32.0
11 Jun	73	A-7D	32.4	155	34.5	0	860	2R	39.9	67.5	20.9	12.5	31.1	32.6	R	27.0	38.2
11 Jun	74	A-7D	31.5	157	34.3	0	-	-	-	-	-	13.7	-	40.5	L	30.0	50.9
												-	-	34.9	R	27.0	42.8
												-	-	24.6	L	22.7	26.4
												-	-	21.0	R	20.5	21.4
												-	-	26.4	L	23.6	29.1
												-	-	28.6	R	24.5	32.1
												-	-	39.0	L	29.5	48.1
												-	-	35.0	R	26.1	43.1
												-	-	31.2	L	26.1	36.1
												-	-	30.9	R	24.5	37.1
												-	-	-	L	-	-
												-	-	-	R	-	-

AF706 FORM 228A
DEC 80

DATA SHEET

DATE

SIDE OF RAILWAY	IMPACT TAPE TENSION (LB X 10 ⁻³)	BRAKE TAPE TENSION (LB X 10 ⁻³)	MAXIMUM AVG CHANGE TUR TEMP (°F)	MAXIMUM AVG CHANGE TUR PRESS (PSI)	MAXIMUM AVG CHANGE TURF TEMP (°F)	MAXIMUM AVG CHANGE TURE PRESS (PSI)	PENDANT NUMBER	TAPE NUMBER	TAPE CONNECTOR	SUPPORTS* AND SPACING (FEET)	ARRESTING SYSTEM	COMMENTS			
L	22.4	25.1	21.5	53.2	15.3	53.0	2	1	1	S	BAK13				
R	19.2	21.6						1	1	S					
L	26.7	38.1	26.4	72.4	19.9	74.5									
R	22.4	30.4													
L	24.8	28.6	23.0	54.8	16.8	56.3									
R	21.6	23.2													
L	29.5	42.8	24.3	82.5	72.7	79.5									
R	23.7	36.0													
STANDARD BAK-12															
L	21.4	26.1	21.8	51.8	-	53.5	5	1	1	R	BAK13				
R	21.4	24.6						1	1	14/18					
L	22.7	35.3	31.6	68.7	16.1	66.8									
R	24.8	36.2													
L	20.5	27.0	21.8	53.6	15.8	54.5									
R	21.4	27.0													
L	19.5	23.2	21.1	46.9	6.1	47.8									
R	20.5	21.4													
L	25.1	40.9	35.2	77.4	17.4	72.1									
R	24.6	39.1													
L	28.6	-	44.1	84.5	31.9	83.1									
R	27.3	41.8													
L	24.2	29.8	19.8	55.3	12.2	48.9									
R	21.4	25.1													
L	26.0	32.6	29.0	73.5	30.5	68.0									
R	27.0	38.2													
L	30.0	50.9	43.5	91.8	39.7	82.3	6								
R	27.0	42.8													
L	22.7	26.4	25.4	49.2	12.2	45.4									
R	20.5	21.4													
L	23.6	29.1	26.9	61.5	24.4	62.3									
R	24.5	32.7													
L	29.5	48.5	31.7	92.0	-	84.3						APPROACH END			
R	26.1	43.8										APPROACH END			
L	26.1	36.3	29.5	78.5	21.9	73.2						APPROACH END			
R	24.5	37.2										APPROACH END - HOOK			
L	-	-	-	-	-	-						HIT & SKIPPED OVER			
R	-	-	-	-	-	-						DEPRESSED CABLE			

*R - Rails HD - Heavy Duty Donuts
S - Standard Donuts

2

FLIGHT DATA

AF NO FLIGHT NO TEST
ENGINE NO FUEL CONFIGURATION

DATE	PROGRAM NUMBER	AIRCRAFT TYPE	AIRCRAFT WEIGHT (LB x 10 ⁻³)	AIRCRAFT SPEED (Knots) [†]	KINETIC ENERGY	ENGAGEMENT DISTANCE From (Feet)	AIRCRAFT RUNOUT (Feet)	LATERAL DISPLACEMENT (Feet)	IMPACT HOOKLOAD (LB x 10 ⁻³)	BRAKE HOOKLOAD (LB x 10 ⁻³)	MAXIMUM DASHPOI LOAD (LB x 10 ⁻³)	MAX HOOK SIDELOAD (LB x 10 ⁻³)	"MAXIMUM" HOOKLOAD (LB x 10 ⁻³)	SIDE OF RUNWAY
27 Apr	27	A-7D	25.7	91	9.6	0	795	15R	-	-	18.4	20	-	L
												13.7		R
29 Apr	28	A-7D	25.7	94	10.1	0	785	12R	17.9	19.3	19.3	2.4	19.3	L
												5.9		R
29 Apr	29	A-7D	25.4	115	14.8	0	800	23R	24.8	27.5	27.5	1.8	27.5	L
												6.7		R
29 Apr	30	A-7D	25.1	122	16.6	0	810	2R	-	-	14.8	2.4	-	L
												3.6		R
30 Apr	31	A-7D	25.3	131	19.3	0	810	6R	33.9	35.4	-	4.5	35.4	L
												6.6		R
30 Apr	32	A-7D	25.1	138	21.2	0	825	6R	-	-	19.2	3.0	-	L
												5.4		R
30 Apr	33	A-7D	25.0	160	28.4	0	-	-	-	-	-	-	-	L
												-		R
4 May	34	A-7D	25.9	141	22.7	0	820	1L	35.8	39.9	18.4	5.4	39.9	L
												5.4		R
4 May	35	A-7D	25.4	150	25.3	0	840	1R	39.6	43.8	18.8	6.5	43.8	L
												7.1		R
4 May	36	A-7D	25.1	139	21.6	35R	820	10R	34.4	35.8	19.7	7.7	35.8	L
												5.4		R
4 May	37	A-7D	24.9	118	15.4	35L	805	10L	24.1	30.8	18.8	3.0	30.8	L
												5.4		R
5 May	38	A-7D	26.9	117	15.9	50R	805	14R	22.6	31.1	19.4	6.1	31.1	L
												5.5		R
5 May	39	A-7D	25.9	139	22.2	50L	825	14L	30.2	35.8	19.4	5.4	35.8	L
												7.7		R
5 May	40	A-7D	25.5	150	25.5	50R	845	4R	37.8	43.6	20.6	6.7	43.6	L
												11.0		R
7 May	41	A-7D	32.9	113	15.5	0	835	5R	24.8	31.6	20.0	2.4	31.6	L
												3.6		R
7 May	42	A-7D	32.7	123	21.9	0	850	6R	31.6	28.9	20.0	3.6	31.6	L
												3.6		R
7 May	43	A-7D	32.3	131	24.5	0	865	7R	32.5	36.8	20.6	5.4	36.8	L
												3.6		R
11 May	44	A-7D	33.1	147	31.6	0	875	4R	38.2	45.3	20.4	4.2	45.3	L
												6.0		R
11 May	45	A-7D	32.8	162	38.1	0	905	5R	45.3	52.4	22.9	8.3	52.4	L
												6.6		R
11 May	46	A-7D	32.5	138	27.3	0	880	6R	36.4	42.2	20.2	6.0	42.2	L
												6.0		R
13 May	47	A-7D	26.6	155	28.3	0	855	6L	43.8	48.0	20.8	11.9	48.0	L
												6.8		R
13 May	48	A-7D	25.7	165	30.2	0	865	6R	48.1	42.6	22.2	2.9	48.1	L
												5.6		R

AFTIC FORM 228A
DEC 80

[†] e - Estimated

FLIGHT DATA SHEET

TEST DATE
 DURATION

LOAD (LB x 10 ⁻³)	MAX HOOK SIDELOAD (LB x 10 ⁻³)	MAXIMUM HOOKLOAD (LB x 10 ⁻³)	SIDE OF RUNWAY	MAXIMUM AVG TAPE TENSION (LB x 10 ⁻³)	MAXIMUM AVG LT & RT TAPE TENSION (LB x 10 ⁻³)	IMPACT TAPE TENSION (LB x 10 ⁻³)	BRAKE TAPE TENSION (LB x 10 ⁻³)	MAXIMUM BRAKE PRESS (PSI)	TELL TAPE BRAKE PRESS (PSI)	MAXIMUM TAPE PEEL (PPH)	PENDANT NUMBER	TAPE NUMBER	TAPE CONNECTOR	ARRESTING SYSTEM	SUPPORTS AND SPACING	COMMENTS			
2.4	0.0	-	L	11.4	11.7	14.0	9.3	227	275	5800	2	1	1	BAK12	9				
	13.7		R		11.0	14.3	7.6	238	960	8200		1	1		5				
3	2.4	19.3	L	12.7	12.9	13.3	12.4	286	350	575									
	5.9		R		12.4	14.3	10.5	270	875	1120									
7.5	1.8	27.5	L	15.6	14.9	14.9	14.9	428	450	700									
	6.7		R		16.3	17.7	14.9	428	850	850									
1.8	2.4	-	L	17.5	17.2	17.2	17.2	476	500	725									
	3.6		R		17.7	19.1	16.2	476	1750	725									
	4.5	35.4	L	18.7	19.1	18.1	20.0	682	675	760									
	6.6		R		18.2	18.6	17.7	667	1650	840									
2.2	3.0	-	L	19.6	19.6	19.1	20.0	682	775	820									
	5.4		R		19.6	21.4	17.7	667	1750	840									
	-	-	L	-	-	-	-	-	-	-									
	-	-	R	-	-	-	-	-	-	-									
2.4	5.4	39.9	L	21.7	21.0	19.1	22.9	878	500	880	3								
	5.4		R		22.4	22.8	21.9	857	1450	840									
1.8	6.5	43.8	L	23.2	22.0	21.0	22.9	905	770	900									
	7.1		R		24.3	25.7	22.8	952	1770	900									
7.7	7.7	35.8	L	20.8	19.6	19.6	19.6	714	675	620									
	5.4		R		21.9	23.3	20.5	810	1570	810									
1.8	3.0	30.8	L	17.0	17.7	17.7	17.7	619	575	920									
	5.4		R		16.3	16.8	15.8	500	565	840									
2.4	6.1	31.1	L	16.8	14.9	14.9	14.9	428	500	660									
	5.5		R		18.6	19.5	17.7	619	725	840									
2.4	5.4	35.8	L	20.0	20.4	20.4	20.4	810	525	820									
	7.7		R		19.5	20.4	18.6	714	775	870									
2.6	6.7	43.6	L	23.0	20.4	20.4	20.4	738	675	880									
	11.0		R		25.6	28.8	22.4	952	1150	990									
2.0	2.4	31.6	L	15.9	16.0	14.6	17.3	571	550	790									
	3.6		R		15.8	15.8	15.8	558	1150	870									
2.0	3.6	31.6	L	16.8	17.2	15.8	18.6	545	650	760									
	3.6		R			17.3	15.5	590	1350	960									
2.6	5.4	36.8	L	19.1		17.3	20.0	636	600	840									
	3.6		R			20.0	19.1	715	1350	900									
2.4	4.2	45.3	L	22.6		20.5	25.1	884	800	940									
	6.0		R			22.3	22.3	790	1200	960									
2.9	8.3	52.4	L	25.6	25.1	21.4	28.8	1095	1000	1030									
	6.6		R		26.0	26.0	26.0	1000	1550	1020									
2.2	6.0	42.2	L	20.0		18.6	21.4		700	840									
	6.0		R			20.5	18.6		1600	870									
2.8	11.9	48.0	L	24.5		22.9	27.6	908	875	960	4				HD	APPROACH END			
	6.8		R			23.3	24.2	954	1700	930					12				
2.2	2.4	48.1	L	22.7		23.0	24.0	908	950	1000									
	5.6		R			22.7	20.9	952	2075	1180									

HOOK HIT AND BOUNCED
OVER FLATTENED CABLE

HD APPROACH END
12

APPROACH END

*p - Rails HD Heavy Duty Donuts
S - Standard donuts

FLIGHT DATA SHEET

..... AF NO FLIGHT NO TEST
ENGINE NO .. FUEL CONFIGURATION

[illegible]

AFFTC FORM 228A
DEC 80

† e- Estimated

TA SHEET

DATE

MAXIMUM* AVG TAPE TENSION (LB x 10 ⁻³)	MAXIMUM* AVG LT & RT TAPE TENSION (LBx10 ⁻³)	IMPACT TAPE TENSION (LB x 10 ⁻³)	BRAKE TAPE TENSION (LB x 10 ⁻³)	MAXIMUM* BRAKE PRESS (PSI)	TELL TALE BRAKE PRESS (PSI)	MAXIMUM TAPE REEL RPM	PENDANT NUMBER	TAPE NUMBER	TAPE CONNECTOR	ARRESTING SYSTEM	SUPPORTS* AND SPACING	COMMENTS		
20.3	20.0	20.0	20.0	722	800	840	4	1	1	BAK12	HD	APPROACH	END	
	20.5	21.8	19.1	727	250	840		1	1		12			
16.1	16.7	16.2	17.1	500	525	700								
	15.5	15.5	15.5	500	625	820								
18.4	19.1	16.2	21.9	620	600	850								
	17.7	16.8	18.6	620	1450	1240								
22.1	23.3	19.5	27.0	905	800	940								
	20.8	18.6	23.0	820	1325	960								
25.5	25.9	20.9	30.9	1050	825	1000								
	25.0	21.8	28.2	1000	1000	1200								
30.7	30.5	23.8	37.2	1370	1000	1150	5							
	30.8	25.2	36.3	1320	1125	1240								
21.2	21.0	18.1	23.8	818	950	820								
	21.4	19.5	23.2	785	375	900								
19.4	20.5	19.1	21.9	682	775	840								
	18.2	16.8	14.5	620	275	870								
23.6	21.9	18.1	25.7	905	950	850								
	25.3	22.9	27.6	955	450	1000								
29.4	31.5	25.7	37.2	1410	1000	1270								
	27.2	22.9	31.4	1340	600	1210								
21.3	19.1	18.1	20.0	590	800	850								
	23.4	21.9	24.8	710	575	840								
26.5	28.1	24.8	31.4	1140	1050	1240								
	24.8	21.9	27.6	1050	850	1000								

*R - Rails HD - Heavy Duty Donuts
S - Stansaru ucunat

APPENDIX II

Deficiency Reports Submitted For Action

Appendix II contains a summary of deficiencies that were submitted for action in deficiency reports (DR's). DR's were formal serialized reports officially recognized by the A-7D Program Management Office. The DR system was used throughout the basic A-7D Category II program and the Category II FSEP.

An "F" in front of the DR numbers indicates that the deficiency was discovered in the Category II FSEP. Those DR numbers without an "F" were discovered in the basic Category II program, but were processed and submitted during the FSEP. The first DR numbers indicate the sequential numbers of working DR's which were originated, but not necessarily submitted to the A-7D Program Management Office for action. The second DR numbers indicate the sequential numbers of the formal DR's submitted formally to the A-7D Program Management Office for action.

A-7D CATEGORY II DEFICIENCY REPORT (DR) AIR FORCE FLIGHT TEST CENTER EDWARDS AFB, CALIF

I. GENERAL: DATE: 24 May 71 MDRS REPORT: None

DR NO: F406-184

ACFT S/N: ALL MAJ SUBSYSTEM: Landing Gear WUC: 13400

II. DEFICIENCY: Unreliable design of arresting hook subsystem.

III. DEFICIENCY CIRCUMSTANCES/DESCRIPTION/CAUSE:

Problems encountered with the A-7D arresting hook subsystem seriously hinder the compatibility between the A-7D and Air Force arresting gear. This is attributed to the design of the hook shoe and hook actuator system.

The arresting hook shoe (P/N 616050-1SS) is not properly designed for optimum engagement reliability. The nose of the hook shoe assumes an off the runway attitude which increases proportionally with hook shank travel. For example, at 40 degrees (from the horizontal) of hook travel, the nose of the hook shoe is one-fourth inch above the runway; however, at 70 degrees of hook travel, the nose of the hook shoe is two inches above the runway surface. Hook travel between 50 degrees and 60 degrees has been typical at the instant of engagement. This condition makes the hook assembly very susceptible to outside disturbances, thus causing hook bounce and missed engagements.

When the hook shank has traveled 40 degrees, the hook holddown force at the runway surface is 370 pounds while at 70 degrees, this force reduces to 200 pounds. The reduction in hook holddown force at large degrees of hook travel is too great.

IV. LOCAL CORRECTIVE ACTION: None

V. DEFICIENCY CLASSIFICATION:

A. MISSION IMPACT:

Probable hook bounce and missed engagement of the arresting cable during operational or emergency landings.

B. SAFETY HAZARD CLASSIFICATION (HIL-S-882): IV

C. CORRECTION CATEGORY: Mandatory

VI. RECOMMENDATIONS:

1. Redesign the hook shoe so that the point stays on the runway surface, regardless of hook shank angle.

2. Redesign the hook actuator system to provide greater hook holddown force at large angles of hook travel.

Nathaniel O. Devoll
NATHANIEL O. DEVOLL, Major, USAF
A-7D Project Officer

Cys to: PMA235-B/AIR5103F2
NPRO Dallas
HQ TAC/DMMFO/DRF
HQ ASD/ASNNX/ASTDN-30/ASTDN-20/ASTH11/
ASTFF
NATC/CT-10/INSURV
OCAMA/MMCTC/MMC-7/MMEW

NOT REPRODUCIBLE

A-7D CATEGORY II DEFICIENCY REPORT (DR)
AIR FORCE FLIGHT TEST CENTER
EDWARDS AFB, CALIF

I. GENERAL:

DR NO.: F-408-185 DATE: 17 June 1971 MORS REPORT: None
ACFT S/N: 67-1583 MAJ SUBSYSTEM: Main Landing Gear Tire MJC: 13ACB

II. DEFICIENCY: Unsatisfactory A-7D main landing gear tires.

III. DEFICIENCY CIRCUMSTANCES/DESCRIPTION/CAUSE: The main landing gear tires, on A-7D aircraft S/N 67-1583, were cut by the impact of the arresting cable on 60 - 70 percent of the 74 barrier/arresting gear engagements made during the A-7D Category II Follow-on Systems Evaluation Program (FSEP). All tests were conducted using the BAK 12 or BAK 13 arresting gear installation on the South Base Runway 06 at the AFOTC, Edwards AFB, California. Damage illustrated in photographs 1505-71 and 1506-71 is typical of that sustained during a single pass over the cable. The damage shown in photographs 1507-71 and 1508-71 is typical of that sustained after using the tire for one or more arresting gear engagements after the original cutting had taken place on a previous run. Damage at times consisted of tread separation over six inches in length.

The fact that these tires were used on repeated arresting gear engagements has no bearing on the problem. If the Air Force is going to use the A-7D on runways having multiple arresting gear installed, running over these cables on takeoff or landings at speeds greater than 100 knots will cause damage as shown in the attached photographs.

The logistic support for replacing damaged aircraft tires will be increased considerably. Though no tire blow outs were encountered during this test program, tread separation did occur. Tire blow outs are a definite probability due to this damage and the dangers that are associated with them. It is mandatory that an improved tire be purchased for the A-7D in order to avert the incidents/accidents associated with tire blow outs during operational use.

The tire material should be improved to withstand the arresting cable slam when passing over it. The new tire must also be designed to operate at a higher speed than 174 knots.

IV. LOCAL CORRECTIVE ACTION: Frequent tire changes were made when the tire cuts appeared to be excessive. The aircraft was limited to landing speeds below the 174 knot tire limit speed during this test. There was no reason to land or takeoff over an arresting cable on the Edwards AFB main runway, so this tire damage was not encountered during normal day-to-day operation.

V. DEFICIENCY CLASSIFICATION:

A. MISSION IMPACT: If the A-7D operates from bases with multiple arresting gear, increased logistic support, possible damage to aircraft from blown tires, and possible injury to personnel.

B. SAFETY HAZARD CLASSIFICATION (MIL-S-38130): III

C. CORRECTION CATEGORY: Mandatory

VI. RECOMMENDATIONS: Procurement of an improved A-7D main landing gear tire.

Nathaniel O. Devoll

NATHANIEL O. DEVOLL, Major, USAF
A-7D Project Officer

4 Attachments

1. 1505-71
2. 1506-71
3. 1507-71
4. 1508-71

Cys to:

PHI235-8/AIR5103F2

WPRO Dallas

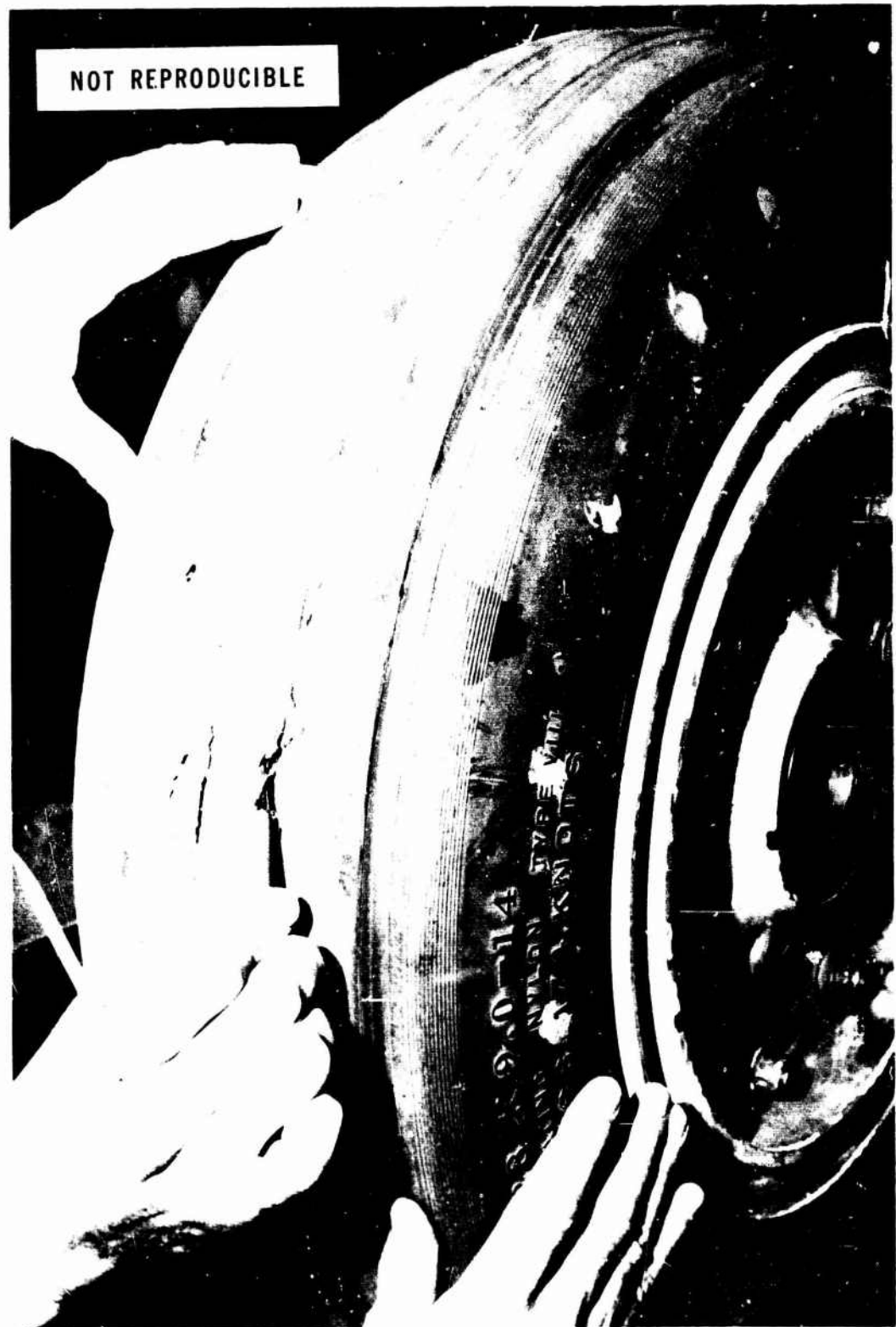
HQ TAC/DHMFQ/DRF

HQ ASD/ASNHX/ASTDN-30/ASTDN-20/
ASTHM/ASTFF

NATC/CT-10/INSURV

OCAHA/HMCTC/HMC-7/MNEV

NOT REPRODUCIBLE



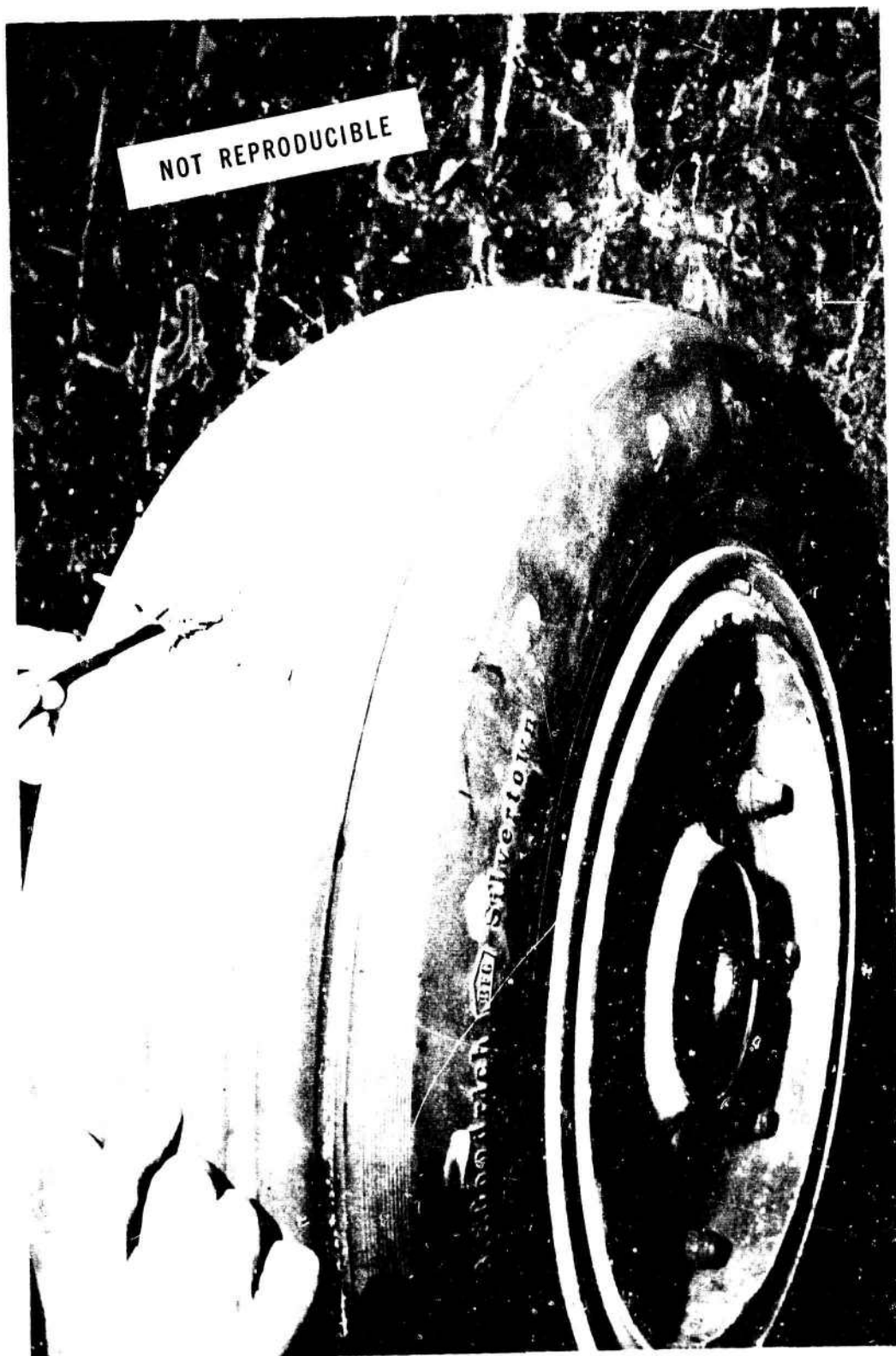
Photograph 1505-71



Photograph 1506-71



Photograph 1507-71



Photograph 1508-71

REFERENCES

1. T.O. 1A-7D-1, A-7D Flight Manual, 15 June 1970, changed 1 January 1971.
2. T.O. 35E8-2-5-1, Aircraft Arresting Barrier-Model BAK-12/E32A, 15 January 1968, changed 1 April 1968.
3. T.O. 35E8-2-7-1, Aircraft Arresting System - Model BAK-13/F48A, 1 November 1969.
4. T.O. 1A-7D-2-7, Landing Gear Systems A-7D, 15 September 1970, changed 1 April 1971.
5. Lucero, Frank N., BAK-12/E32A Portable Aircraft Arresting Barrier, FTC-TDR-63-64, Air Force Flight Test Center, Edwards Air Force Base, California, November 1963.
6. York, David A., First Lieutenant USAF, Phase I Test and Evaluation of the BAK-13/F48A Aircraft Arresting System, FTC-TR-69-3, Air Force Flight Test Center, Edwards Air Force Base, California, May 1969.
7. Fairchild, Frederic P., First Lieutenant USAF, and Hover, Robert C., Major USAF, Category II F-111A Arresting Systems Compatibility Tests, FTC-TR-69-9, Air Force Flight Test Center, Edwards Air Force Base, California, June 1969.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)		2a. REPORT SECURITY CLASSIFICATION	
Air Force Flight Test Center Edwards Air Force Base, California		UNCLASSIFIED	
		2b. GROUP	
		N/A	
3. REPORT TITLE			
Category II A-7D/Arresting Systems Compatibility Tests			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
Final			
5. AUTHOR(S) (First name, middle initial, last name)			
James C. Rogers, Jr., Second Lieutenant, USAF Nathaniel O. DeVoll, Major, USAF			
6. REPORT DATE		7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1971		65	7
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO.		FTC-TR-71-32	
c. Project Directive 71-16		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		N/A	
10. DISTRIBUTION STATEMENT			
This document is to be further distributed by any holder of this report and is to be controlled by the same security classification as the report.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY	
N/A		6510th Test Wing Edwards AFB, California	
13. ABSTRACT			
<p>Seventy arrestments of A-7D, S/N 67-14583, were made on two operational aircraft arresting systems, the standard BAK-12 and the BAK-13. As a result of six approach end engagement arrestments, changes in the Flight Manual approach end engagement procedures were recommended. Runway centerline engagements were made at aircraft weights up to 42,000 pounds. The maximum engagement speed was 167 knots at an aircraft weight of 33,000 pounds. Off-center engagements were also made up to 50 feet from the runway centerline using a 190-foot span between the runway edge sneaves of the arresting systems. Aircraft control problems were not serious except for 50-foot off-center engagements with the BAK-13. Test data indicated that the design limit hookload would only be approached at engagement speeds in excess of 190 knots for both arresting systems. Four tests resulted in missed engagements due to a combination of poor hook shoe attitude and poor cable dynamics. The cable dynamics problem occurred with the rail type arresting cable supports when the A-7D main gear passed between the rails. Further testing of polyurethane rails was recommended to determine optimum spacing for use with the A-7D. Except for the aircraft hook shoe design, the A-7D proved compatible with each aircraft arresting system using donut type cable supports. There were no failures of the standard BAK-12 or the BAK-13 arresting systems. Although not tested, the extended runout BAK-12 was also considered to be compatible with the A-7D aircraft based on results of this test program.</p>			

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
A-7D aircraft aircraft arresting systems BAK-12 arresting system BAK-13 arresting system donut cable supports hookloads approach end engagements off-center engagements cable dynamics						

SUPPLEMENTARY

INFORMATION

E R R A T A

FTC-TR-71-32, Category II A-7D/Arresting
Systems Compatibility Tests, Air Force Flight Test
Center, Edwards AFB, California, July 1971.

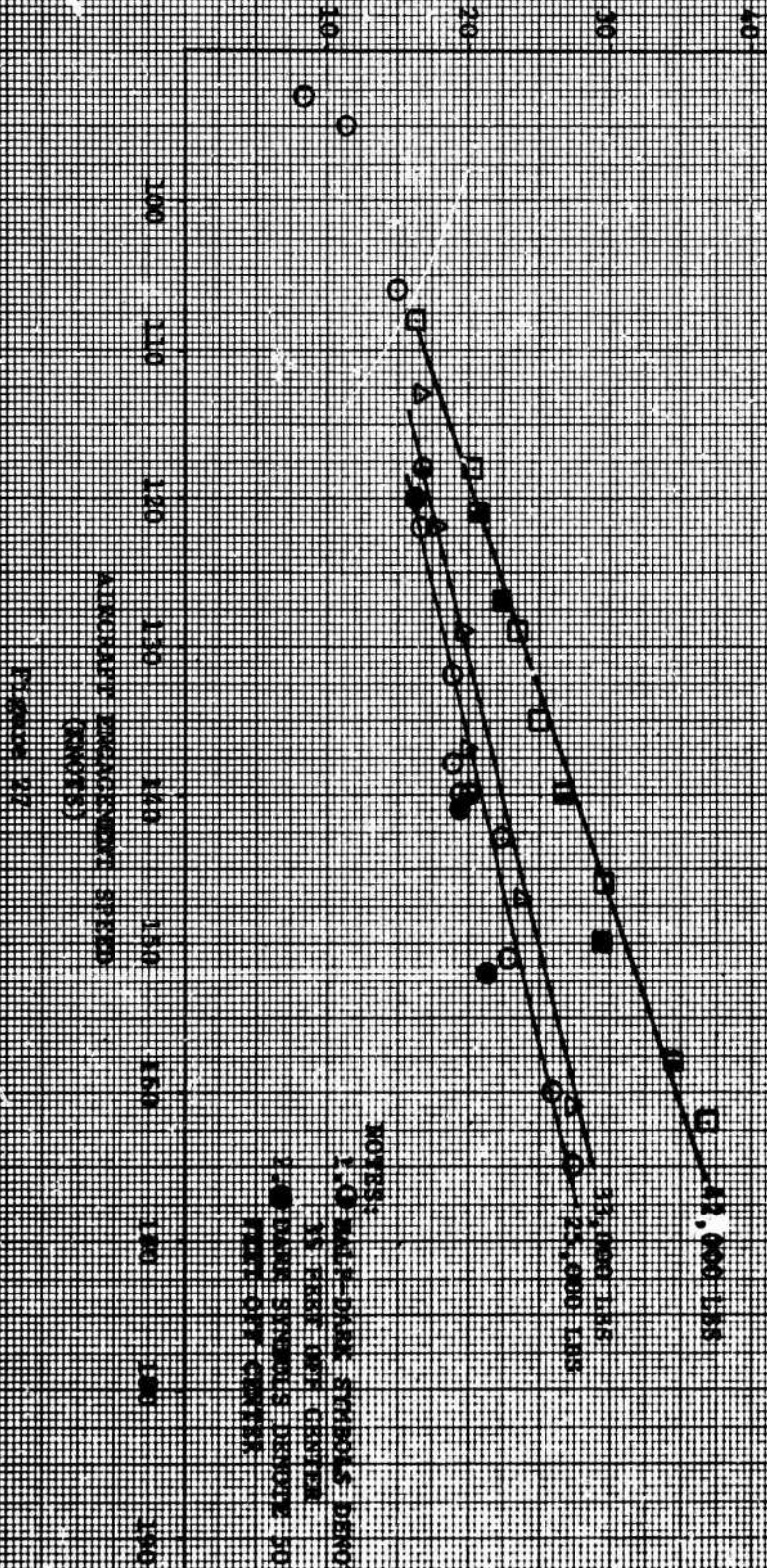
AD-888 9692

Figures 27 and 32 of the original technical report are in error. The attached figures should be substituted for them. These corrected data plots still compare reasonably well within limits of data scatter experienced, to references 5 and 6 of FTC-TR-71-32 as stated on page 39 of that report. The values on the corrected data plots are somewhat higher, however. The higher tape loads shown are of no significance to the A-7D aircraft and figures 12 and 13, which show the maximum aircraft hook loads, are valid. Corrections to figures 27 and 32 have no effect on the conclusions and recommendations to this report.

MAXIMUM AVERAGE BRAKE TAPE TENSION (POUNDS $\times 10^{-3}$)

4700 RPM EVALUATION 28/75
MAXIMUM AVERAGE BRAKE TAPE TENSION PERFORMANCE

BAK-12 CONFIGURATION
950 FOOT RUMPLE
250 FOOT SHAW/58 FOOT SPLIT
AIRCRAFT ENGAGEMENT POINTS CENTERLINE, 35 FT., 50 FT.
AIRCRAFT WEIGHT
○ 25,000 POUNDS
△ 31,000 POUNDS
□ 42,000 POUNDS



NOTES:
1. ○ HALF-DARK SYMBOLS DENOTE
35 FEET ENG. CENTER
2. △ DARK SYMBOLS DENOTE 50
FEET OFF CENTER

